TELESCOPE MAKING 7

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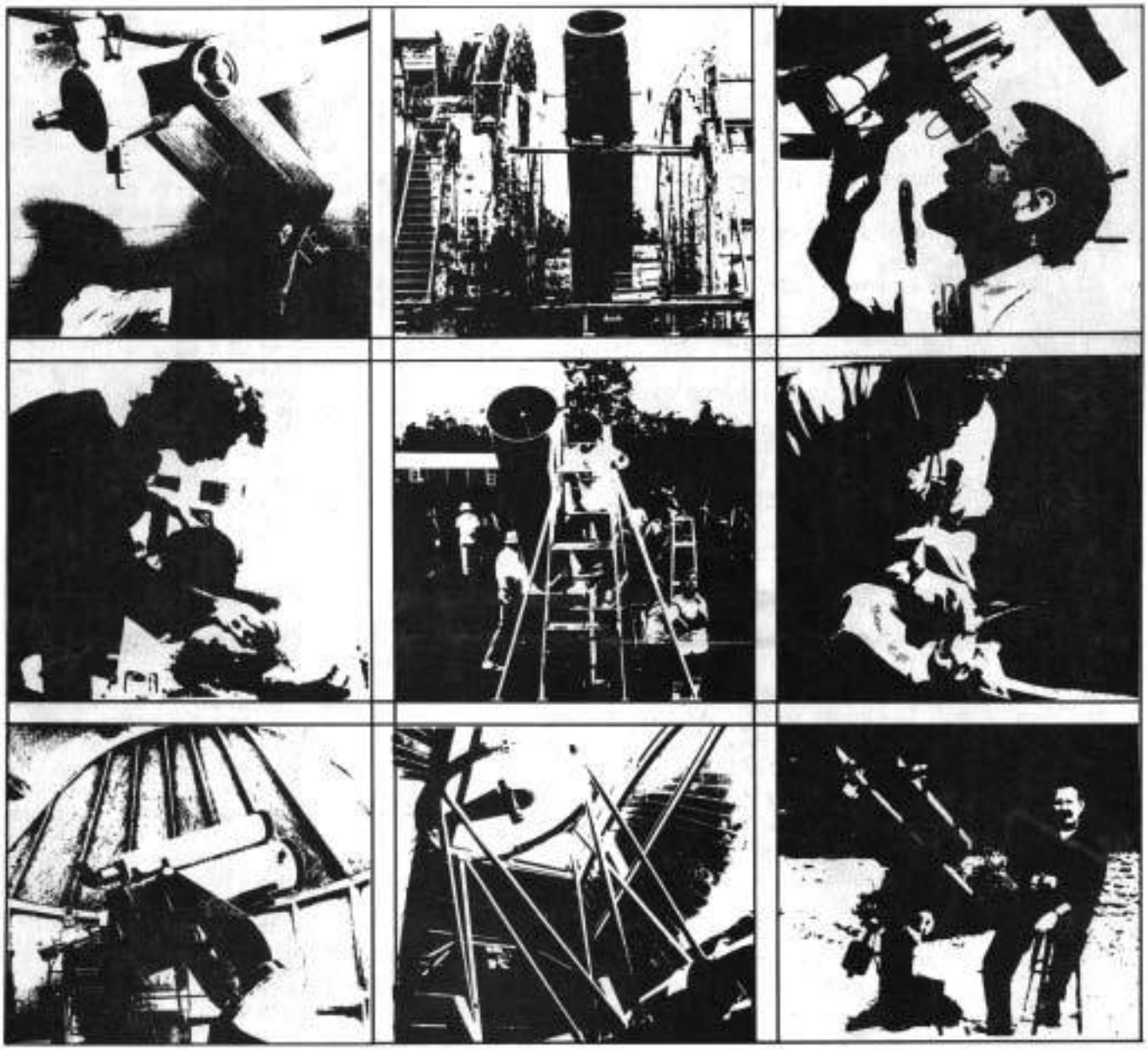
The magazine *for*, *by*, and *about* telescope makers!

Spring 1980



TELESCOPE MAKING

The magazine *for, by* and *about* telescope makers!

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In this issue...

2 Editorial
3 Letters
4 Secondary Mirrors and Spiders
by Robert E. Cox
8 Lord Rosse's Great Telescope
by Thomas Dick
14 Equipment for Deep-Sky Astrophotography
by Walter E. Hamler
20 A Portable Polishing Machine
by Thomas Waineo
24 A 20" Newtonian on an Alt-Azimuth Mount
by Richard Berry
30 Zeroing in with a Long Radius Mirror
by A. L. Woods
32 Short Articles Section
Adjusting a 10" Schiefspiegler
A Handy Chair for Observing
Observing through a Roof Hatch
The 20-Incher in the Rhubarb Patch
34 A Shelter from Streetlights
Wojciech Konefal Observatory
Equatorial Mount for a 10" Reflector
36 Mid-States Regional A.L. Convention
A Mount for a Small Cassegrain
To Giraffe or Not to Giraffe
A Homemade Finder
38 The PEP Gang
by Russ Genet *et al.*
44 The Questar 12
by Ernest B. Wright
45 Simple Astro Mount
by Kenneth S. Hulme
47 Blue Pages Classified Product Directory

Editorial

A lament: This feels, to your long-suffering editor, like the issue that was destined never to be. It all started with a case of the flu which came on like Montezuma's Revenge and lasted weeks. Then, during February and early March, everybody else got sick — one by one. Our production schedule began to slip. Those of you who read ASTRONOMY will see that we introduced several changes in the department structure. Those changes, including the rewrites, editorial conferences, and new layouts, ate up still more time. The new "country sky" Star Dome star map had to be plotted star by star: I did most of that — and ended up with a bad case of eyestrain. Then our Blue Pages were delayed. The net result is we're two weeks late going to press. We also came out rather short on space — so What's New isn't making its usual appearance. My sincere apologies. I hope you'll find lots of useful info in this issue anyway.

New topic: For some time we've toyed with the idea of introducing display advertising in TM. While I feel that such advertising could be a reader service, I want to poll the readership first. Here's the "pro" for ads as I see it: 1) It would give the small firms a chance to reach the market for a low price; 2) It would keep readers informed on who the suppliers are; 3) It would promote healthy competition which would (in the long run) improve the quality of goods; and 4) It would improve the economic viability of TM from AstroMedia Corporation's viewpoint. And the "cons"? 1) You might fear that we would lose the editorial freedom to freely discuss goods and services; 2) We might unknowingly carry ads containing exaggerations or false

claims; and 3) Ads would give TM a commercial feel which you wouldn't like. The $64K question is what do you, TM's readers, think of seeing advertising in our pages? Please drop me a note to let me know what you think and why you think it. Thanks.

The deadline for TM#8 articles is June 1, and the deadline for TM#9 is August 21. For the sake of the sanity of the editor and production crew, try to submit sooner than that. And if you live in the southwest, I'll be at the Riverside Telescope Maker's Conference (Memorial Day Weekend) again this year. I hope to see you then.

Sincerely

Richard Berry

Letters

Amateur Events Coverage?

Dear Sir / As you know, there are a great many groups of amateur astronomers throughout the country. Many of these sponsor conventions, have their own observatories, sponsor Astronomy Day activities and other things for the public, etc. With all of these things going on, it is very seldom that you see anything reported on except for occasional coverage of such large events as the Riverside convention. There are presently few if any ways that an amateur astronomer living on the east coast of the U.S., for example, can learn about the activities of his or her fellow amateurs in the rest of the country. In effect, each group of amateurs is generally quite isolated from any others.

I think that there is a great void here that can be filled and my suggestion is as follows: Expand your coverage of amateur groups and their activities. This can be accomplished in any number of ways. For example, create a new section devoted to coverage of amateurs and their activities in ASTRONOMY magazine itself, or perhaps create an entirely new periodical such as TELESCOPE MAKING that would come out monthly or bimonthly. Groups could be solicited for news about how they run their organizations, what sort of activities they carry out, public response to them, the number of members they have, what sort of projects they undertake, etc.

Offers of a free subscription to your magazine or cash awards to groups could be used as an incentive for submission of material in addition to on-the-spot

48

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Improving Telescope Performance Part 2

Secondary Mirrors and Spiders

In TM #6, we examined the requirements for mounting the primary mirror in a telescope. The next step is to determine how to mount the second optical element. (The mounts shown for a Newtonian diagonal will also serve for a Cassegrain secondary.)

The worst designs for mounting a diagonal use springs in the adjusting system. The best advice I can give you (or a vendor planning to put mechanical accessories on the market) is to avoid the use of springs. If the telescope is going to be put in an observatory where it will receive no hard jolts in handling, then a device using springs can possibly work, but it is still not good practice to use them.

The second major design fault is in the way the position of the diagonal mirror is determined through the use of a threaded shaft passing through a threaded hub. It should be obvious that it's only luck if the optical axis of the primary mirror, after reflecting off the diagonal, passes through the center of the eyepiece holder. It has to be out of line by a maximum of ½ thread or some fraction of a thread travel. Assuming 32 threads per inch on the holding shaft, it's possible to be high or low by up to 1/64th of an inch. Fortunately, you can take up this difference with the tilt bolts by screwing them up or down equally on each bolt to bring the center of the diagonal mirror in to the center of the eyepiece holder.

A third fault is the setscrew that pushes on the threaded rod to lock it in position — in tightening down the setscrew, you'll always shift the shaft out of position! The reason is the loose fit between the threaded rod and the hub. If either one or the other has not been cut for a snug fit, this problem cannot be eliminated. The result: it's a guessing game to try to set the diagonal location so that after the setscrew is tightened the alignment will fall into the proper position.

Of course, the spider assembly is important too. But for now we'll only discuss the support of the central assembly, as there is no need for considering the finest spider if the mirror is inadequately mounted — the cause has been lost.

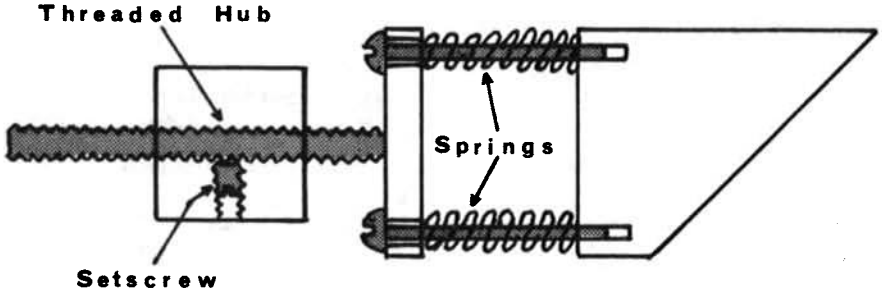
It was possible with the primary mirror cell to eliminate the springs and make simple modifications that resulted in a workable assembly. Is it also possible with the spider hub assembly? Most definitely! This is one of the exciting potentials of telescope making — almost anything can be improved with a little ingenious thought and careful work. So let us see how to rework the assembly described.

First, remove the springs. Chances are the distance between the hub carrying the diagonal and the plate to which the threaded shaft is attached was excessive. Reduce the separation to a minimum by substituting a disk of hard neoprene rubber at the center of the hub. Replace the original bolts with short ones that thread into the bottom hub a few threads depth. To obtain a tilt adjustment, snug down all adjusting bolts until it appears that it is impossible to tighten them further without stripping the bolts out of the hub. Now check to see that the pieces are evenly tightened down and the surfaces involved are parallel to each other.

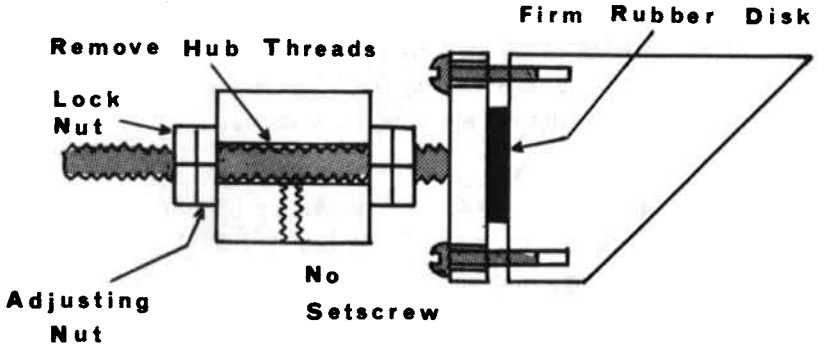
Tilt adjustment in alignment is achieved by slightly loosening the proper bolt, but if you feel that too much adjustment was necessary and not enough tension on the bolts has resulted, then tighten up the assembly and start over, being more careful in how much and which bolt you loosen.

To correct the threaded shaft and hub, first remove the setscrew and throw it

A Poorly Designed Spider Assembly



An Improved Spider Assembly



away. Unscrew the shaft from its hub and drill out the threads from the hub center. This can result in a very sloppy fit of the threaded shaft in the new hole, so it's even better if you can drill an oversize hole in the hub and insert a bushing having a tight fit in the hole and a snug sliding fit over the threads on the rod.

Next place two nuts on the shaft into its hub and down so the bottom of the hub contacts the upper nut. Then place two more nuts on the shaft and bring them down so the bottom one contacts the top of the hub. Take the two nuts, one top and one bottom, and snug them up against the hub, being sure to rotate the diagonal face so it is turned toward the eyepiece holder. Now, by first loosening one nut and tightening the other, it is possible to raise and lower the diagonal to bring the reflected beam of light centrally through the eyepiece holder. Tilting the bottom assembly on its hard rubber base will allow exact alignment. When everything is satisfactory, the two remaining nuts are snugged down against the first two to lock the assembly in permanent alignment.

It is possible, under extreme circumstances, for the bolts that tilt the diagonal to loosen. A drop of cement on one edge of each bolt will eliminate this problem, yet it can be picked off with a razor blade if needed.

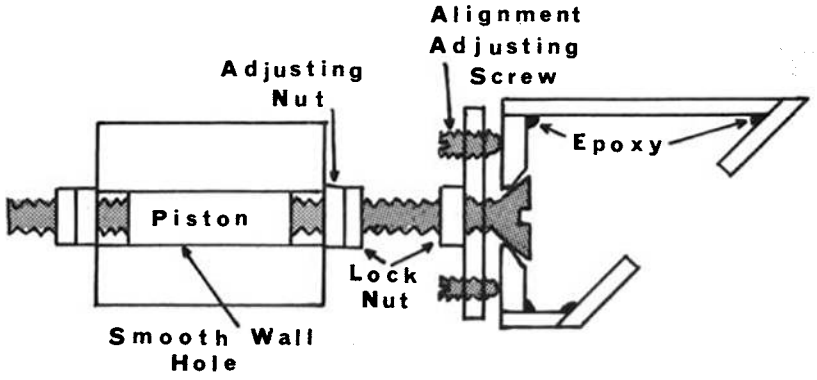
There are too many support systems to make it practical to examine them all and, if necessary, suggest correction methods, but by applying similar basic techniques as just done, it should be possible to improve any item.

The basic methods suggested for primary mirror support systems (in TM #6) also apply to mounting a diagonal or secondary mirror. Since it is impractical to cover them all, let's select the following example as the "classic" case.

Since we are designing this support, it is possible to use the best engineering practices to insure optimum results. First (for stability) the diagonal hub and the spider support should be as close together as possible to minimize torque and hence vibration. Second, the tilt limits should be small. There is no need to have large amounts as such a practice can lead to instability. Third, to minimize radical shifting of the diagonal mirror in adjusting, the tilts should be physically centered around the optical axis. Fourth, all adjustments should have a positive lock to be applied when final alignment has been obtained.

For the TM with a minimum of tools and shop experience to assemble a good spider, the rugged example shown should work well. The main mirror support is a hollow cylinder (this also reduces weight of the unit) with one face cut off square to the tube and the opposite end cut at a 45° angle.

A Rugged Spider Assembly



On the angled face, epoxy a flat plate with a central hole in it to allow you to insert the tilt bolt later on in the assembly. This plate can be elliptical to fit the surface, or it can be roughly so, with final shaping done with a file and sandpaper after it is affixed to the tube.

Now put the back plate in position inside the tube as shown or placed over the outside end as a cap. Reach through the hole in the angled plate and epoxy the second plate in position. If recommended to speed curing, you can heat the parts in an oven to set the epoxy quicker. Now insert the tilt bolt in the hole in the center of the flat plate and thread a round flat plate down the rod until it just clears the back of the diagonal mount. To lock this in position, run a nut down the bolt and snug it up against the flat plate. Screw the four adjusting screws in the back plate and adjust them until the flat plate and the rear diagonal are parallel.

Having completed this part of the assembly, run two nuts down the rod until they are close to the first nut. The upper end of the rod is now screwed into the piston — a smooth cylinder which will slide in the vane support hub — and a second short threaded rod is likewise screwed into the top of the piston. Two nuts are then placed at the far end of the rod.

Those having the facilities can further increase the versatility of the unit by using a long threaded rod which will screw through a hollow threaded piston and which can therefore be located along the rod and not fixed as in the first case.

The nuts closest to the spider vane hub are now run up until they contact the hub. Be sure that the piston is centrally located in the hub. By loosening one nut and tightening the opposite one, it is now possible to shift the diagonal mirror toward and away from the primary mirror to locate it correctly relative to the eyepiece opening. When positioned, the second nut is run down against the first and tightened with a socket wrench to lock the assembly into alignment.

Final alignment uses the four adjusting screws (two of which are shown) to tilt the diagonal until optical alignment has been reached. The screws should have rounded heads to easily achieve any necessary rotational adjustment by turning the diagonal support physically by hand around the tilt bolt head. The tilt adjusting screws should be slotted — and not as allen heads — as it is easier to insert a small screwdriver and rotate it than to try to insert the six-sided allen head wrench in the confines of a telescope tube.

No locking nuts are shown on the unit, as in a small diagonal mount there could be a problem of sufficient space and a conflict with the central locking nut. However, a drop of Duco cement at one edge will hold the screws in position if you wish.

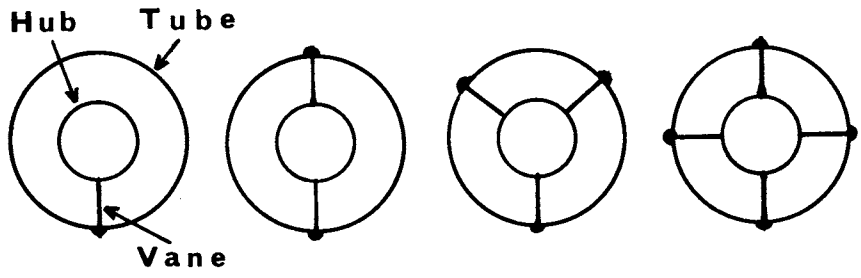
If you insist on using a three-point support for alignment adjustment, modify the usual equilateral triangle design by converting it to one that makes a right angle triangle with the three screws, as was shown for the primary mirror mount (see page 34 of TM #6).

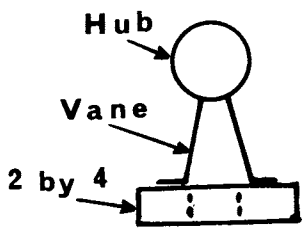
To obtain a different angle on the bolt head and countersink, if you make the latter with a 100° cutter and with the bolt head having an angle of 82°, sufficient movement will automatically be provided.

Having designed a central support system for a diagonal or secondary mirror, how can you hold the hub in the center of the tube and on the optical axis? The ideal solution is a window on which the diagonal is mounted. A few years ago a high quality plate glass was available, twin polished parallel plate, from which it was possible to select glass with good enough quality for a telescope window, especially a low power instrument. Unfortunately, this glass is no longer made and the commercial substitute, float glass, is not satisfactory. (A commercial firm that supplies optics for telescopes was planning to make windows, but due to the mild recession, and business in general, the plans have been delayed for now.)

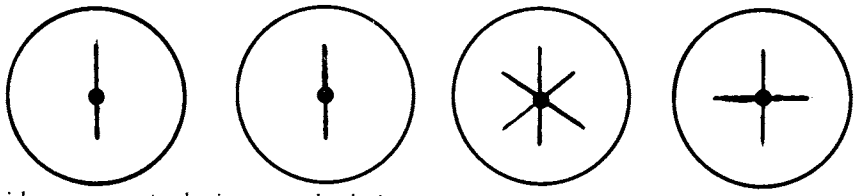
For the general hobbyist, with the cost

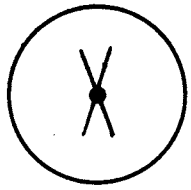
Spider Support Systems





Bright Star Spike Pattern





Spider support designs and their corresponding diffraction spikes on a bright star.

of a good quality window impractically high, the remaining solution is the construction of a "spider" at the top of the tube to support the diagonal holder. Telescope spiders do not have the beauty or intricacy of the web of an insect, but can assume some unusual shapes in some instruments.

Having a structure in the light path of a celestial object, it is quite natural to expect some effect on the final image. First, there will be a loss of light with the largest amount from the hub and diagonal. Light loss from a spider arm is very small. The most serious effect of a central obstruction and spider is the light that is diffracted from the edges of the parts. Particularly interesting are the diffraction effects of the arm that supports the diagonal. Each spider vane will generate two spikes (or lines of light) extending from opposite sides of the object. You may prefer to avoid odd numbers of vanes as the final result will be a bothersome doubling of the number of spikes on bright star images, though each spike will be half as bright.

The simplest support is a single vane that extends from one wall or side of the telescope tube, but due to its design, this form of support must be rather thick to prevent flexure as the telescope is shifted to various sky locations.

It is a logical step to increase the strength of the support and at the same time reduce the width for the arm by making the spider a two-arm device with the arms opposite each other. For added rigidity, the arm can be a single piece of metal extending across the tube. Now the diffraction effects overlap each other and spike effects are minimized.

Some telescopes don't have any tube but use instead a rigid beam, quite often a 2 x 4, with the mirror mounted on one end and the diagonal at the other. For a rigid support that will hold alignment in transportation, it is suggested the spider be made a two-arm "V". Diffraction will give four spikes in the image plane, but as we will see, this is the usual number in most telescopes. Although the diffraction pattern in this design will not be symmetrical around the star image, this can be ignored in general observing.

The three-legged spider was at one time general practice in amateur telescopes, as it gives maximum structural strength with minimum structure. The effects of diffraction are six faint spikes on a bright star image as opposed to the four brighter spikes seen with four-vane spiders.

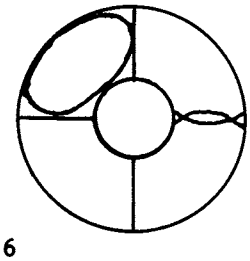
By far the most popular spider is the four-support one — the diffracted spikes falling upon the opposing strut. One danger: if the spider arms are not exactly 180° opposed, you'll get eight spikes. The opposing struts make it much easier to center the assembly in the tube as you have a push-pull of opposing bolts for easy control.

To minimize the spikes, or remove them from view by spreading them around, a number of specially shaped spiders have been designed. The earliest published account is that of A. Couder at the Observatory of Paris, who reported on his design in *L'Astronomie* in January 1934.

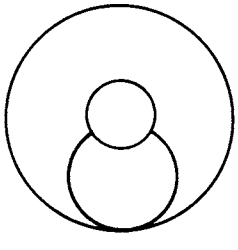
More modern designs incorporate curved arms that are relatively simple to construct. In actual practice, these curved spiders do not eliminate the diffraction effects, but instead, spread the diffracted light around the field, generally in the vicinity of the image, so no spike or other form of light concentration is seen. Although this approach helps in double star separation, it is not an ideal solution to observing low faint contrast details, as any stray light, no matter how diffuse, detracts from the observation. This is why so many lunar and planetary observers prefer using a refractor or reflecting TCT (Tilted

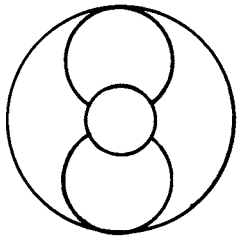
Spike Suppressing Supports

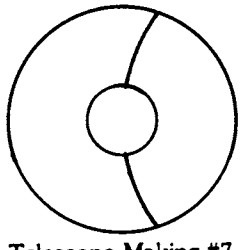
Couder - 1934

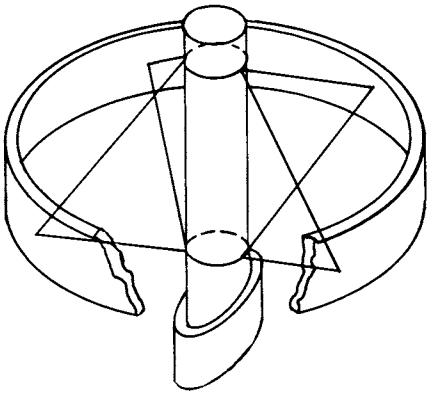


Some Modern Methods









Component Telescope, such as a Yolo or Schiefspiegler) in such work.

The ideal thickness for a vane is the minimum possible. The general rule is that the vane be no thicker than 1% the mirror diameter. For the very best performance, the maximum central obstruction size is 5% the primary mirror diameter — but it's hardly ever practical.

In an article that appeared in the December 1959 *Astronomical Journal*, authors Joseph W. Kantorski and Edgar Everhart presented a paper on "Diffraction Effects Produced by Obstructions in Reflecting Telescopes of Modest Size" (which was also reprinted in the September 1960 issue of *Sky & Telescope*). In these articles it was suggested, for a support that sensibly has no diffraction, that the use of thin wires to support the central hub be considered. The wires cannot run radially from the center, but instead, must be in a pattern similar to the spokes of a bicycle wheel where the wires are opposed in pairs, with a minimum of two different centers.

Paul Valleli of the Boston ATMs made a wire spider back in the '60s and it performed well with no diffraction effects visible from the wires. (See also Kevin Medlock's wire supported spider in the Riverside report in TM #4.) It has proved easy to secure the same tension on the wires, as all you have to do is pluck them like a harp, and when all the wires have the same note, they all have the same tension. For stability, the length of the central support should be longer than a regular one, but this disadvantage is more than offset by the advantage of no apparent spider diffraction.

It is necessary to attach the spider to the tube. Care should be taken that the tension needed on the spider supports does not tend to collapse or warp the tube out of round — this is especially true of the wire-type spider. Generally, wide washers under the head of the bolt that extends through the tube will be sufficient, but the addition of a stiffening ring on the tube is a worthwhile idea. A piece of malleable soft aluminum rolled into a circle to fit the tube will also add character to the unit. By sanding or cutting the opposite sides of the ends of the ring where they overlap to a taper, the ring can be fastened together in a neat manner without any plates to extend above the regular surface. To make the ring solid, they can be epoxied together, or several small flathead bolts can be used to hold the ring parts together. Since so many people have trouble with epoxy cements, it is recommended that even in the use of this material, two small bolts be used to insure permanent security of the two parts.

Mounting the diagonal mirror on the 45° face of the central support has always been a problem. One solution has been three small clips extending over the face of the mirror surface. As with the primary mirror mounting in its cell, if clips are used they should extend across the face of the optics about 1/64th of an inch (0.015") at most to keep any diffraction effects at a minimum. If the supports are metal, then they can be soldered on, but eventually the glass must be removed for recoating so this is not really a good idea. Small setscrews into the base are effective but be sure they are secure, or if one or more ever vibrate loose in handling, the diagonal mirror can fall onto the primary mirror surface with damaging effects to both pieces.

Some people place a second tube over the glass hub support with a rolled or turned edge on the 45° face holding the mirror in place. The edge loss in light gathering is negligible in professionally made units, as the lip is so small. It is necessary to have a setscrew through the side of the cover and into the base, and often a slot is made in the back of the cover through which the setscrew passes. It is better if this slot is not open at either end, as an open end could, if the setscrew loosens, allow the cover and diagonal mirror to fall upon the primary.

Since 1961, I have been mounting diagonal and small secondary mirrors by cementing them to their support surfaces. The mirrors are cemented onto the back supports using Pliobond cement and a piece of hard billiard felt. To attach the diagonal to its hub, first coat the hub with a thin layer of Pliobond and immediately press the felt upon the cement and allow the assembly to dry thoroughly (about 60 to 90 minutes). (It is better if the back of the diagonal has a rough surface, but under no circumstances should you try to grind a surface to remove the polish. This can relieve stresses in the glass and cause the figure to spring out of shape. Use the diagonal as received, polished or ground back.) Now coat the diagonal back with a thin layer of Pliobond and immediately press it down on the felt, carefully centering it before making final contact with the felt. In another 60 to 90 minutes the assembly should be ready for mounting in the telescope. A Schiefspiegler 2.2-inch secondary mounted in this fashion has been attached to its backing for many years with no sign of mechanical or optical problems.

It should be quite obvious to the reader that a great many more possible solutions exist that can yield a vibration-proof (or nearly so) spider mount. We'd like to encourage you to develop your own designs, and TELESCOPE MAKING would like to hear from such persons, with the intent of publishing any outstanding developments, especially in cases with work that can be done with simple hand tools by hobbyists with little experience in instrument construction.

Robert E. Cox
Associate Editor
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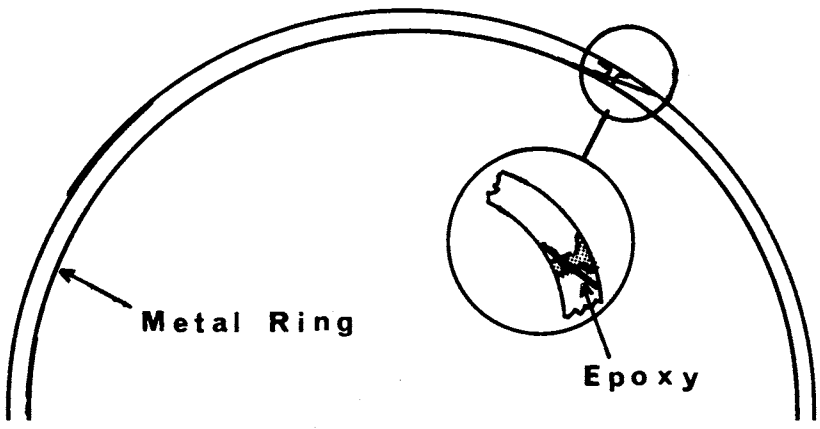
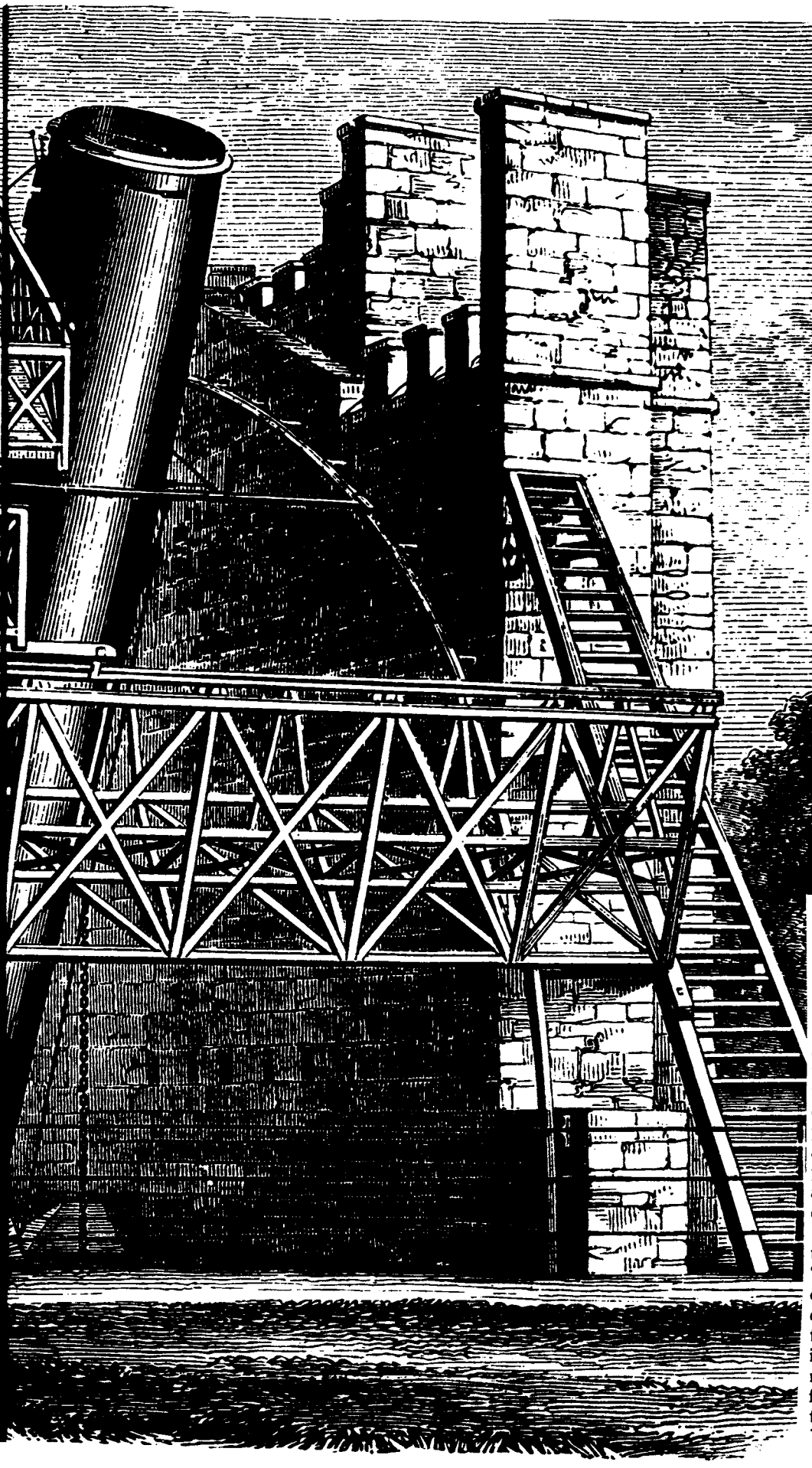
Overlapping the ends of a metal ring to strengthen either the ends of a tube or reinforce the tube area where the spider bolts are located.

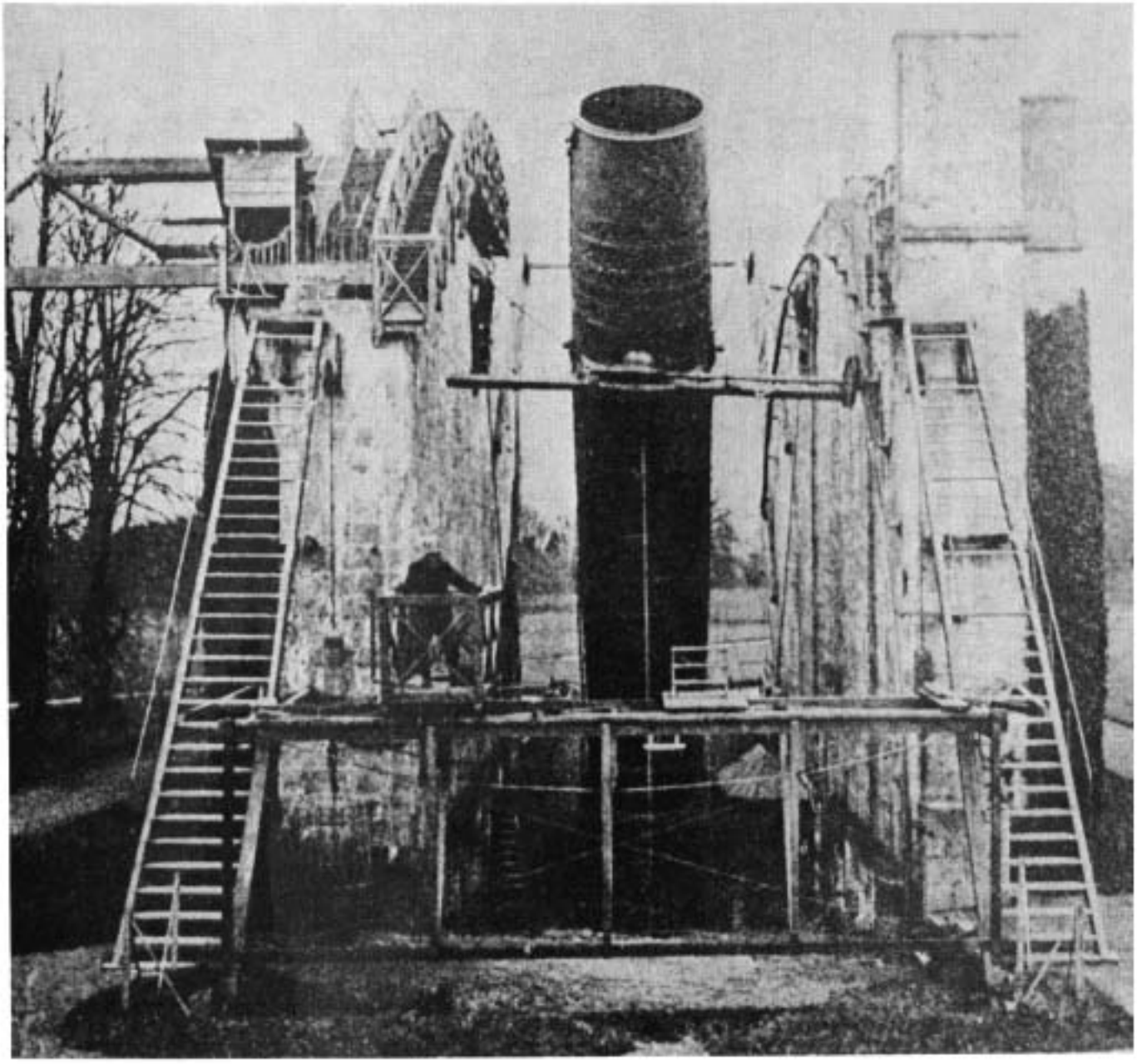




LORD ROSSE'S GREAT TELESCOPE

This telescope, the largest and most magnificent that ever was attempted, reflects the greatest honour on the genius, the inventive powers, and the scientific acquirements of its noble contriver, as well as on the elevated station in which he is placed. With rank and fortune, and every circumstance that usually unfit men for scientific pursuit, he has set a bright example to his compeers of the dignity and utility of philosophical studies and investigations, and of the aids they might render to the progress of science, were their wealth and pursuits directed in a proper channel.

Previously to his lordship's attempting the construction of his largest, or "Monster Telescope," he had constructed one with a speculum of three feet in diameter, which was considered one of the most accurate and powerful instruments that had ever been made, not excepting even Sir Willian Herschel's forty-feet reflector. In the account of this telescope published in the Philosophical Transactions for 1840,



◄ his lordship speaks of the possibility of a speculum of six feet in diameter being cast. At that time it was considered by some as little short of a chimera to attempt the construction of such a monstrous instrument; but the idea no sooner occurred to this ingenious and persevering nobleman than he determined to put it to the test, and the result has been attended with complete success.

The materials of which this speculum is composed are copper and tin, united very nearly in their atomic proportions, namely, copper 126.4 parts, to tin 58.9 parts. This compound has a specific gravity of 8.8, and is found to preserve its lustre with more splendour, and to be more free from pores than any other.

A foundry was constructed expressly for the purpose of casting the speculum. Its chimney, built from the ground, was 18 feet high, and 16½ square at the base, tapering to four at the top. At each of its sides, communicating with it by a flue, was sunk a furnace eight feet deep and 5½ square, with a circular opening four feet in diameter. About seven feet from the chimney was erected a large crane, with the necessary tackle for elevating and carrying the crucibles from the furnace to the mould, which was placed in a line with the chimney and crane, and had three iron baskets supported on pivots hung round it; and four feet farther on was the annealing oven. The crucibles which contained the metal were each two feet in diameter, 2½ deep, and together weighed one ton and a half. They were of cast iron, and made to fit the baskets at the side of the mould. These baskets were hung on wooden uprights, or pivots; to one of these, on each side, was attached a lever, by depressing which it might be turned over, and the contents of the crucible poured into the mould.

The bottom of the mould was made by binding together tightly layers of hoop iron, and turning the required shape on them edgewise. This mould conducted the heat away through the bottom, and cooled the metal towards the top in infinitely small layers, while the interstices, though close enough to prevent the metal from escaping, were sufficiently open to allow the air to penetrate. This bottom was six feet in diameter and 5½ inches thick, and was made perfectly horizontal by means of spirit levels, and was surrounded by a wooden frame.

A wooden pattern the exact size of the speculum being placed on the iron, sand was well packed between it and the frame, and the pattern removed. Each of the crucibles containing the melted metal was then placed in the basket, and everything being ready for discharging their contents, they were at the same instant turned over, and the mould being filled, the metal in a short time safely set into the required figure. While it was red hot, and scarcely solid, the framework was removed, and an iron ring connected with a bar which passed through the oven being placed round it, it was drawn in by means of a capstan at the other side, on a railroad, when charcoal being lighted in the oven, and turf fires underneath it, all the openings were built up, and it was left for sixteen weeks to anneal.

It was cast on the 13th of April, 1842, at 9 o'clock in the evening. The crucibles were ten hours heating in the furnaces before the metal was introduced, which in about ten hours more was sufficiently fluid to be poured. When the oven was opened the speculum was found as perfect as when it entered it. It was then removed to the grinding machine, where it underwent that process, and afterward was polished, without any accident having occurred.

This speculum weighed three tons, and lost about one-eighth of an inch in grinding. Lord Rosse has since cast another speculum of the same diameter four tons in weight. He can now, with perfect confidence, undertake any casting, so great an improvement has the form of mould which he has invented proved. The speculum was placed on an equilibrium bed, composed of nine pieces, resting on points at their centres of gravity. The pieces were lined with pitch and felt before the speculum was placed on them. The speculum box is also lined with felt, and pitched: this prevents any sudden change of temperature affecting the speculum by means of the bad conducting power of the substances employed. A vessel of lime is kept in connexion with the speculum box to absorb the moisture, which otherwise might injure the mirror.

The process of grinding was conducted under water, and the moving power employed was a steam-engine of three-horse power. The polisher is connected with the machinery by means of a large ring of iron, which loosely encircles it; and instead of either the speculum or the polisher being stationary, both move with a regulated speed. The ring of the polisher, and therefore the polisher itself, has a transverse and a longitudinal motion; it makes 80 strokes in the minute, and 24½ strokes backward and forward for every revolution of the mirror, and at the same time 1-72/100th strokes in the transverse direction. The extent of the latter is 27/100ths of a diameter of the speculum. The substance made use of to wear down the surface was emery and water: a constant supply of these was kept between the grinder and the speculum. The grinder is made of cast iron, with grooves cut lengthwise, across, and circularly on its face.

The polisher and speculum have a mutual action upon each other: in a few hours, by the help of the emery and water, they are both ground truly circular, whatever may have been their previous defects. The grinding is continued till the required form of surface is produced, and this is ascertained in the following manner: there is a high tower over the house in which the speculum is ground, on the top of which is fixed a pole, to which is attached the dial of a watch; there are trapdoors which then open, and by means of a temporary eyepiece, allow the figure of the dial to be seen in the speculum brought to a slight polish. If the dots on the dial are not sufficiently well defined, the grinding is continued; but if they appear satisfactory, the polishing is commenced. It required six weeks to grind it to a fair surface. The polisher was cut into the grooves, to prevent the abraded matter from accumulating in some places more than in others; a thin layer of pitch was spread over it; it was kept up till the machinery brought it to a fine black polish. The length of time employed for polishing the six feet speculum was six hours.

This large telescope is now completed, or nearly so. The tube is 56 feet long, including the speculum box, and is made of deal [wood] one inch thick, hooped with iron. On the inside, at intervals of eight feet, there are rings of iron three inches in depth and one inch broad, for the purpose of strengthening the sides. The diameter of the tube is seven feet. It is fixed to mason-work in the ground by a large universal hinge, which allows it to turn in all directions. At 12 feet distance on each side a wall is built, 72 feet long, 48 high on the outer side, and 56 on the inner, the walls being 24 feet distant from each other, and lying exactly in the meridional line. When directed to the south, the tube may be lowered till it becomes almost horizontal; but when pointed to the north, it only falls till it is parallel with the earth's axis, pointing then to the pole of the heavens. Its lateral movements take place only from wall to wall, and this commands a view for half an hour on each side of the meridian; that is, the whole of its motion from east to west is limited to 15 degrees. At present it is fitted up in a temporary way to be used as a transit instrument; but it is ultimately intended to connect with the tube-end galleries machinery which shall give an automaton movement, so that the telescope shall be used as an equatorial instrument.

All the works connected with this instrument are of the strongest and safest kind; all the iron work was cast in his lordship's laboratory by men instructed by himself, and every part of the machinery was made under his own eye by the artisans in his own neighborhood, and not a single accident worth mentioning happened during the whole proceeding.

The expense incurred by his lordship in the erection of this noble instrument was not less than twelve thousand pounds! besides the money expended in the construction of the telescope of three feet diameter. Sufficient time has not yet been afforded for making particular observations with this telescope; but from slight trials which have been made, even under unfavourable circumstances, it promises important results. Its great superiority over every telescope previously constructed consists in the great quantity of light it reflects, and the brilliancy with which it exhibits objects, even when high powers are applied.

It has a reflecting surface of 4071 square inches, while that of Herschel's 40 feet telescope had only 1811 square inches on its polished surface, so that the quantity of light reflected from the speculum is considerably more than double that of Herschel's largest reflector. This instrument has already exceeded his lordship's expectations. Many appearances before invisible in the Moon have been perceived, and there is every reason to expect that new discoveries will be made by it in the Nebulae, double and triple stars, and other celestial objects. The following is an extract of a communication from Sir James South on this subject, addressed to the editor of the "Times:"

"The leviathan telescope on which the Earl of Rosse has been toiling upward of two years, although not absolutely finished, was on Wednesday last directed to the sidereal heavens. The letter which I have this morning received from its noble maker, in his usual unassuming style, merely states that the metal, only just polished, was of pretty good figure, and that with a power of 500 the nebula known as No. 2 of Messier's catalogue was even more magnificent than the nebula No. 13 of Messier, when seen with his lordship's telescope of three feet diameter and 27 feet focus. Cloudy weather prevented him from turning the leviathan on any other nebulous object. ➤

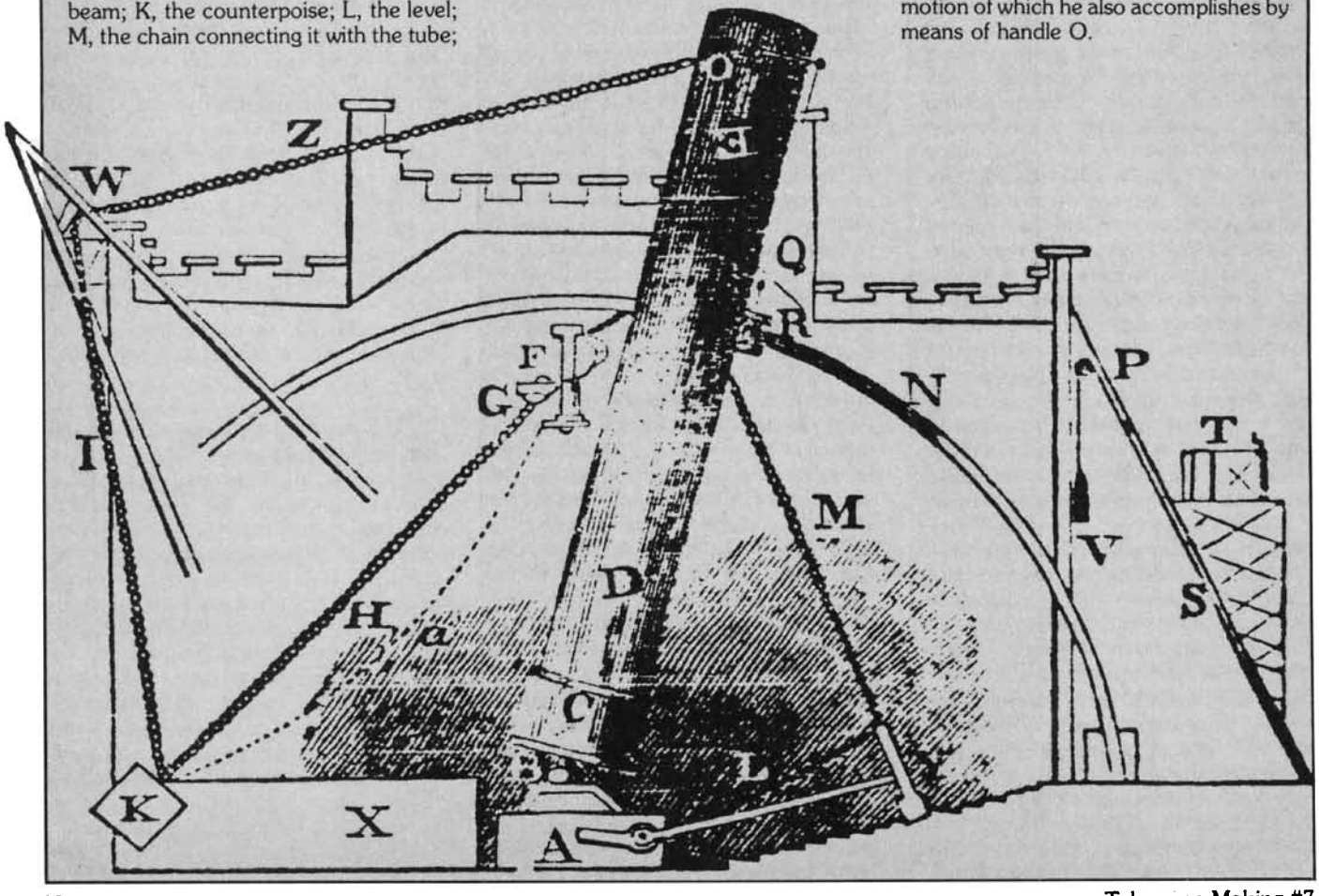
Thus, then, we have all danger of the metal breaking it before it could be polished overcome. Little more, however, will be done with it for some time, as the earl is on the eve of quitting Ireland for England to resign his post at York as president of the British Association. I look forward with intense anxiety to witness its first severe trial, when all it various appointments shall be completed, in the confidence that those who may then be present will see with it what man has never seen before. The diameter of the large metal is six feet, and its focus 54 feet; yet the immense mass is manageable by one man. Compared with it, the working telescopes of Sir William Herschel, which in his hands conferred on astronomy such inestimable service, and on himself astronomical immortality, were but playthings."

The following is a more recent account of observations made by this telescope, chiefly extracted from Sir James South's description, inserted in the *Times* of April 16th, 1845, and the "Illustrated London News" of April 19:

"The night of the 5th of March, 1845, was the finest I ever saw in Ireland. Many nebulae were observed by Lord Rosse, Dr. Robinson, and myself. Most of them were, for the first time since their creation, seen by us as groups, or clusters of stars; while some, at least to my eyes, showed no such resolution. Never, however, in my life did I see such glorious sidereal pictures as this instrument afforded us. Most of the nebulae we saw I certainly have observed with my own large achromatic; but, although that instrument, as far as relates to magnifying power, is probably inferior to no one in existence, yet to compare these nebulae, as seen with it and the six-feet telescope, is like comparing, as seen with the naked eye, the dinginess of the planet Saturn to the brilliancy of Venus. The most popularly-known nebulae observed this night were the ring nebulae in the Canes Venatici, or the 51st of Messier's catalogue, which was resolved into stars with a magnifying power of 548, and the 94th of Messier, which is in the same constellation, and which was resolved into a large globular cluster of stars, not much unlike the well-known cluster in Hercules, called also the 13th of Messier."

Perfection of figure, however, of a telescope must be tested, not by nebulae, but by its performance on a star

The drawing shows a section of the machinery connected with this telescope. It exhibits a view of the inside of the eastern wall, with all the machinery as seen in section. A is the mason work on the ground; B, the universal joint, which allows the tube to turn in all directions; C, the speculum in its tube; D, the box; E, the eyepiece; F, the moveable pulley; G, the fixed one; H, the chain from the side of the tube; I, the chain from the beam; K, the counterpoise; L, the level; M, the chain connecting it with the tube; Z, the chain which passes from the tube to the windlass over a pulley on a trussbeam, which runs from W to the same situation on the opposite wall: the pulley is not seen; X is a railroad, on which the speculum is drawn either to or from its box: part is cut away, to show the counterpoise. The dotted line "a" represents the course of the weight R as the tube rises or falls: it is a segment of a circle, of which the chain I is the radius. The tube is moved from wall to wall by the ratchet and wheel at R; the wheel is turned by the handle O, and the ratchet is fixed to the circle on the wall. The ladders in front, as shown in the preceding sketch, enable the observer to follow the tube in its ascent to where the galleries on the side-wall commence. These side-galleries are three in number, and each can be moved from wall to wall by the observer after the tube, the motion of which he also accomplishes by means of handle O.



of the first magnitude. If it will, under high power, show the star round and free from optical appendages, we may safely take it for granted it will not only show nebulae well, but any other celestial object as it ought. To determine this point, the telescope was directed to Regulus with the entire aperture, and a power of 800, and "I saw," says Sir James, "with inexpressible delight, the star free from wings, tails, or optical appendages; not, indeed, like a planetary disk, as in my large achromatic, but as a round image resembling voltaic light between charcoal points; and so little aberration had this brilliant image, that I could have measured its distance from, and position with any of the stars in the field with a spider's-line micrometer, and a power of 1000, without the slightest difficulty; for not only was the large star round, but the telescope, although in the open air, and the wind blowing rather fresh, was as steady as a rock.

"On subsequent nights, observations of other nebulae, amounting to some thirty or more, removed most of them from the list of nebulae, where they had long figured, to that of clusters; while some of these latter, more especially the 5th of Messier, exhibited a sidereal picture in the telescope such as man before had never seen, and which for its magnificence baffles all description.

"Several double stars were seen with various apertures of the telescope, and with powers between 360 and 800; and as the earl had before told us we should — before the speculum was inserted in the tube, in consequence of his having been obliged to quit the superintendence of the polishing at the most critical part of the process — we found that a ring about six inches broad, reckoning from the circumference of the speculum, was not perfectly polished, and to that the little irradiation seen about Regulus was unquestionably referrible. The only double stars of the first class which the weather permitted us to examine with it were Xi Ursae Majoris, and Gamma Virginis, which I could have measured with the greatest confidence. D'Arrest's comet we observed on the 12th of March, with a power of 400, but nothing worthy of notice was detected.

"Of the Moon, a few words must suffice. Its appearance in my large achromatic of 12 inches aperture is known to hundreds of readers; let them then imagine that with it they look at the moon, while with Lord Rosse's six-feet they look into it, and they will not form a very erroneous opinion of the performance of the leviathan. On the 15th of March, when the moon was seven days old, I never saw her unilluminated disk so beautifully, nor her mountains so temptingly measurable. On my first looking into the telescope, a star about the seventh magnitude was some minutes of a degree from the moon's dark limb, and its occultation by the moon appeared inevitable. The star, however, instead of disappearing the moment the moon's edge came in contact with it, apparently glided on the moon's dark face, as if it had been seen through a transparent moon, or as if the star were between me and the moon. It remained on the moon's disk nearly two seconds of time, and then disappeared. I have seen this apparent projection of a star on the moon's face several times, but from the great brilliancy of the star, this was the most beautiful I ever saw. The cause of this phenomenon is involved in impenetrable mystery."

Following is a description of the great Rosse telescope, along with part of the buildings with which it is connected. In the interior face of the eastern wall a very strong iron arc of about 43 feet radius is firmly fixed, provided with adjustments, whereby its surface facing the telescope may be set very accurately in the place of the meridian. On this bar lines are drawn, the interval between any adjoining two of which corresponds to one minute of time on the equator.

The tube and speculum, including the bed on which the speculum rests, weigh about 15 tons. The telescope rests on a universal joint, placed on masonry about six feet below the ground, and is elevated or depressed by a chain and windlass; and although it weighs about 15 tons, the instrument is raised by two men with great facility: of course, it is counterpoised in every direction. The observer, when at work, stands in one of four galleries, the three highest of which are drawn out from the western wall, while the fourth or lowest has for its base an elevating platform, along the horizontal surface of which a gallery slides from wall to wall by a machinery within the observer's reach, but which a child may work.

When the telescope is about half an hour east of the meridian, the galleries, hanging over the gap between the walls, present to a spectator below an appearance somewhat dangerous; yet the observer, with common prudence, is as safe as on the ground, and each of the galleries can be drawn from the wall to the telescope's side so readily, that the observer needs no one else to move it for him.

The telescope is at present of the Newtonian construction, and, consequently, the observer looks into the side of the tube at the upper end of the telescope; but it is proposed to throw aside the plane speculum, and to adapt it to the front view, so that the observer will sit or stand with his back towards the object, and his face looking down upon the speculum; and in this position he will sometimes be elevated between 50 and 60 feet above the ground. As yet, the telescope has no equatorial motion, but it very shortly will; and at no very distant day, clockwork will be connected with it, when the observer will, while observing, be almost as comfortable as if he were reading at a desk by his fireside.

I shall conclude the description of this wonderful instrument in the words of Sir James South:

"What will be the power of this telescope when it has its Le Mairean form" (that is, when it is fitted up with the front view), "it is not easy to divine. What nebulae will it resolve into stars? in what nebulae will it not find stars? how many satellites of Saturn will it show us? how many will it indicate as appertaining to Uranus? how many nebulae never yet seen by mortal eye will it present to us? what spots will it show us on the various planets? will it tell us what causes the variable brightness of many of the fixed stars? will it give us any information as to the constitution of the planetary nebulae? will it exhibit to us any satellites encircling them? will it tell us why the satellites of Jupiter, which generally pass over Jupiter's face as disks nearly of white light, sometimes traverse it as black patches? will it add to our knowledge of the physical construction of nebulous stars? of that mysterious class of bodies which surround some stars, called, for want of a better name, 'photospheres'? will it show the annular nebulae of Lyra merely as a brilliant luminous ring, or will it exhibit it as thousands of stars arranged in all the symmetry of an ellipse? will it enable us to comprehend the hitherto incomprehensible nature and origin of the light of the Great Nebula of Orion? will it give us, in easily appreciable quantity, the parallax of some of the fixed stars, or will it make sensible to us the parallax of the nebulae themselves? finally, having presented to us original portraits of the moon and of the sidereal heavens, such as man has never dared even to anticipate, will it, by Daguerreotype aid, administer to us copies founded upon truth, and enable astronomers of future ages to compare the moon and heavens as they then may be with the moon and heavens as they were? Some of these questions will be answered affirmatively, others negatively, and that, too, very shortly; for the noble maker of the noblest instrument ever formed by man 'has cast his bread upon the waters, and will, with God's blessing, find it before many days.' "

Thomas Dick, L.L.D.
from "The Practical Astronomer" (1859)

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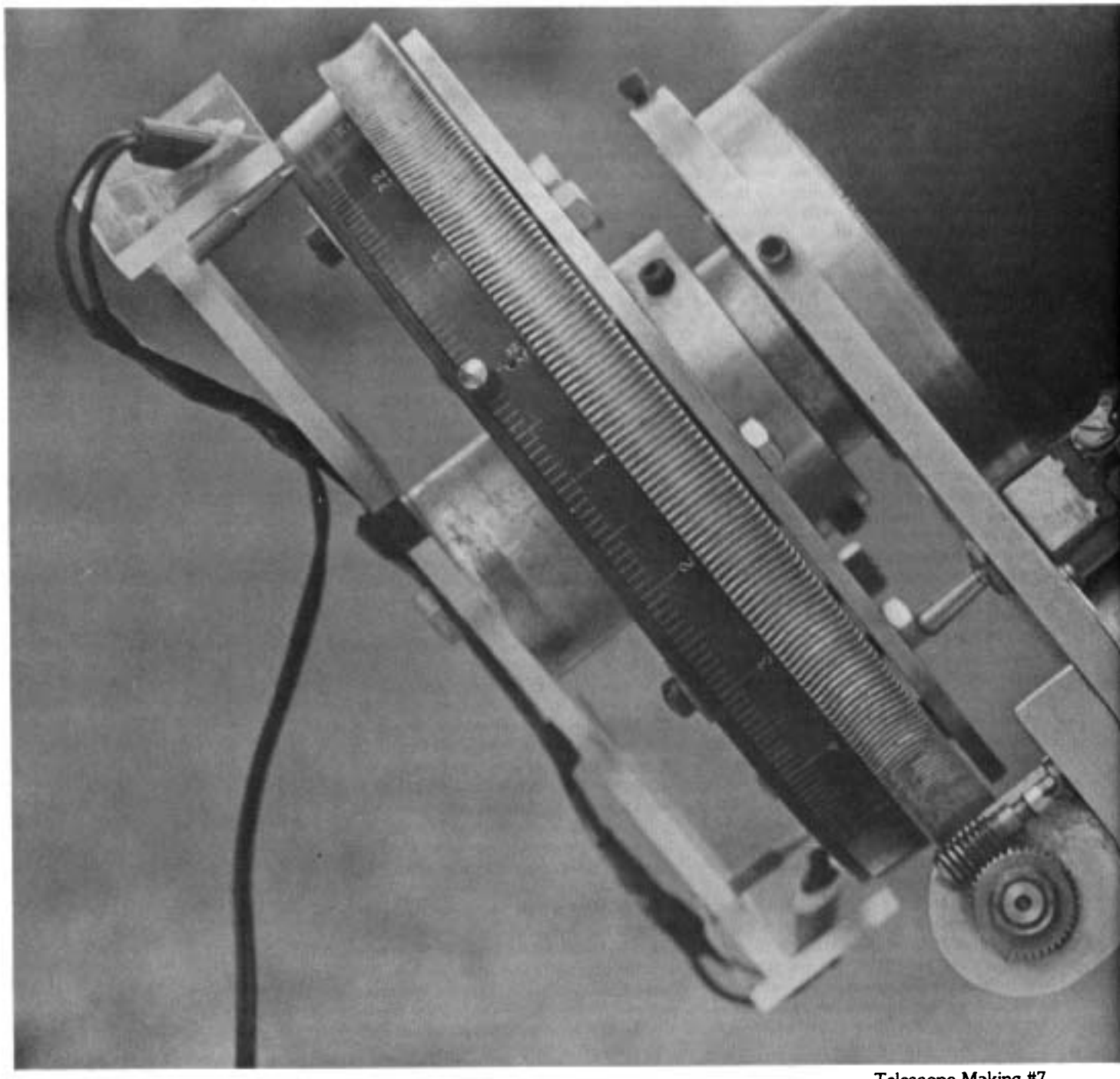
Equipment for Deep-Sky Astrophotography

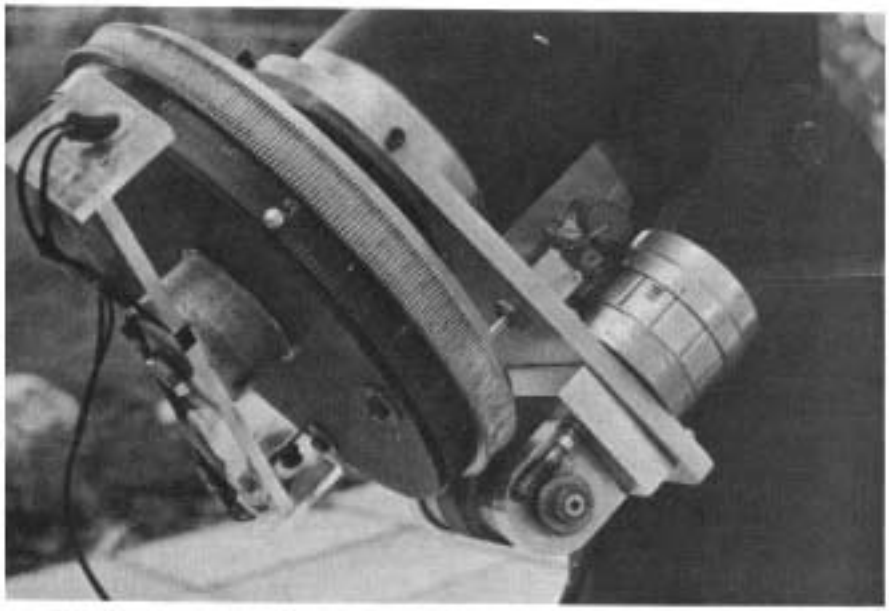


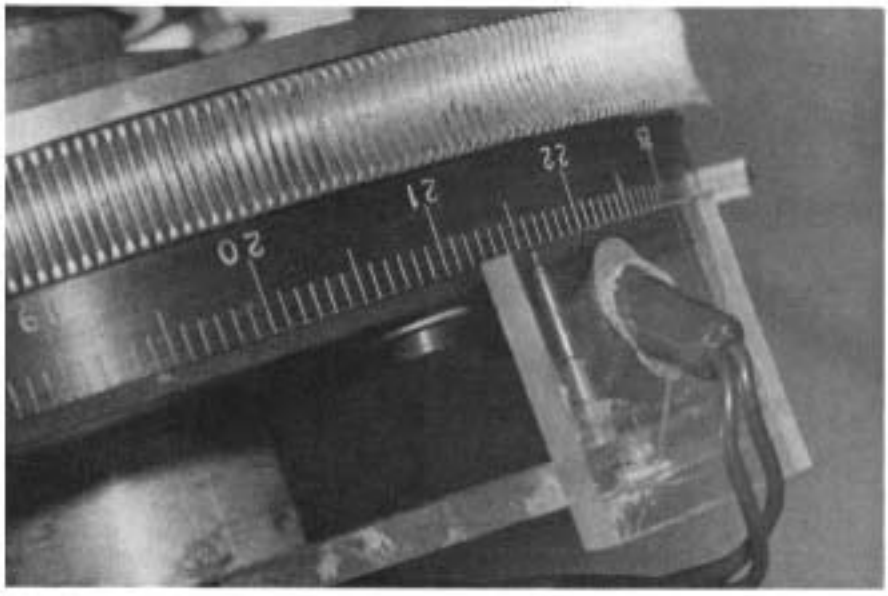
The first and foremost consideration for getting great astrophotos is figuring "What kind of telescope?" Most people expect that the answer could only be "A very big telescope — and nothing less." But the more knowledgeable you become in astronomy and the greater your familiarity with telescopes and astrophotography, the more you realize that smaller is sometimes better.

What's going to work best also depends on what you're going to photograph. As a general rule, the larger the telescope, the more detail and the less field appears in the pictures. Any accomplished astrophotographer can show you that good photographs can be taken with most any type of telescope. But different kinds of telescopes lend themselves to some tasks better than others, and it all depends on what kind of pictures you want to take.

Now, I'll admit I'm biased toward certain kinds of pictures. I photograph nebulae and galaxies that aren't usually any bigger than a degree or two, and I find a resolution of about five seconds of arc sufficient. I use the 35 mm film format for its convenience. For my kind of astrophotography, a Newtonian telescope is best. The simple optical configuration is easily collimated, dewing problems are very rare, and the relatively fast f/ratios available allow for conveniently short exposure times. For portability, I've stayed with an aperture

The polar and dec. housings are 4" o.d. x 10" long, with ⅜" wall thickness 6061 aluminum. The shafts are solid steel, 2" o.d. x 16" long. The center column is 8" o.d. x ⅛" wall and 23" high; its legs are ¾" pressboard sandwiched between ¼" aluminum plates. The RA is driven by a 8.2" Schmidt with 1.5" stainless steel worm. Note the tangent arm drive on the declination axis.





of just eight inches.

If I wanted to do wide-fields with up to five or ten degrees coverage (perhaps surveying variable stars or Milky Way goodies), I'd use a Schmidt camera or precision doublet lens. For wider fields than that, I'd need an astrographic lens or a war surplus aerial lens. If galaxies, which have small angular diameters, were my forte, I'd need a bigger Newtonian, or a longer f/ratio, or Cassegrain optics for greater plate scale and resolution. But a medium aperture Newtonian, with its almost ideal middle-of-the-road capabilities, is good for almost any project.

The Mirror

Convinced? Well then, let's get on with Newtonians: What's the "best" f/ratio? The coma-free field of a simple paraboloid is discouragingly small, but the field in which coma is acceptably small is large enough to cover the entire 24 mm x 36 mm format of the 35 mm film frame camera with sharp images at f/6. The fields of faster paraboloids diminish quite quickly, as you can see in the following table:

f/ratio:	4	5	6	7	8
field size:	0.6	1.1	1.8	2.8	4.3

A focal ratio of f/5 or f/6 would seem to be a good compromise between photographic speed and field with a 35 mm format. Since these are probably the most common f/ratios, unless you have other special considerations, such as a larger image size or a wider field, they are the ones to use.

Most telescopes in use by amateurs today are intended primarily for visual use, and any photographic capabilities were an afterthought. Though manufacturers and ATMs are now wising up, you're going to find yourself required to upgrade almost any telescope — to take a camera body, hold a guidescope, guide accurately, or simply stay rigidly in alignment — before it'll be suitable for astrophotography.

Focuser

In order to allow full illumination to the film plane, use a 2" focusing unit. The focuser must be rigid, and should be low-profiled to hold the camera close to the telescope tube. It should have at least

Cup and cone (tapered roller bearings) used on both axes. The aluminum housings were bored .002" smaller than the o.d. of the bearing cup. When installed, the housings were heated to .350° F in an oven — the bearing cups were frozen to -10° F. They almost dropped in place. The shafts are cadmium-plated to a depth of .0005", creating a .001" interference fit with the bearing cones. This allows the preload on the bearings to be adjusted.

two setscrews positioned 90° apart to hold the camera securely. If it's a rack and pinion type focuser, a provision for minimizing backlash is desired. If a simple threaded tube is used, a setscrew for locking at the determined focus is handy. These requirements can usually be met with a focusing unit specifically designed for astrophotography, or by modifying an existing 2" focuser (see Tom Dessert's article in TM #5).

Diagonal Mirror

The size of the diagonal is very important. Most Newtonians are equipped with a diagonal mirror intended for visual use with standard 1¼" eyepieces. These small diagonals typically provide full 100% illumination over a 0.3" to 0.75" circle. The resulting falloff at the corners of a 35 mm negative gives severe vignetting. Obviously a larger diagonal mirror is required. Rather than make a general recommendation, the following formula is provided. By inserting the proper numbers for your conditions, the precise size can be determined.

First solve: $D = T + 2H + 1$, then use in
$N = (MD + 2IF - ID)/2F$

T = tube diameter
I = image size of 100% illumination (recommend 1")
H = height of focuser fully racked in
M = mirror diameter
F = focal length

Example: 8" f/5 with a 2.5" high focuser
$D = 9.5 + 2(2.5) + 1 = 15.5$
$N = (8x15.5 + 2x1x40 - 1x15.5)/2x40$
$N = 2.35$

In the example, a choice between the commonly available 2.14" or 2.60" diagonal mirror would be satisfactory; the smaller mirror would provide a little less illumination at the corners, but not noticeable. Precise sizes are available from custom manufacturers at somewhat higher prices.

Spider, Diagonal Holder

The spider and diagonal holder must be of sufficient strength and rigidity to securely hold the diagonal mirror without movement or flexure. Go over these units carefully and eliminate all sources of wobble or looseness. (See Robert Cox's article in this issue.) I personally recommend attaching the diagonal to its holder with contact cement. This holds the mirror securely without any stress, especially if the holder utilizes small tabs for mirror location.

Mirror Cell

A lot of people stress the importance of keeping the mirror gently in its cell in order not to cause any stress that would change the optical figure. We must compromise here, as any movement of the mirror during an exposure is detrimental.

Read Robert Cox's article in TM #6 — and then follow his recommendations. If you just can't do anything else, at least put cork strips around the mirror edge to prevent any lateral movement within the cell. Make the mirror retaining clips tight enough to completely prevent longitudinal movement — but no tighter. I use contact cement at the mirror support points for added security.

The Telescope Tube

Depending on the telescope design and f/ratio, the tube may or may not be a problem. Short-tube optics won't usually have any problems unless the tube is thin or flexible. The long tubes found on larger Newtonians and refractors usually have flexure problems unless they're some extremely stiff material.

Fiberglass is probably the most common material used today in Newtonians. Its main advantage is light weight and good thermal stability. Its main disadvantage is that it's very brittle when made too thin.

Aluminum used to be very popular, but has become relatively expensive lately. For small telescopes it's still a good buy, especially in refractors and small Newtonians used for guidescopes.

Spiral wound cardboard tube, commonly called Sonotube, is popular with large Newtonians. A few coats of polyester resin for moisture sealing and rigidity help Sonotube last. Sonotube's biggest advantage is that it's inexpensive. Use internal bracing for deep-sky astrophotography with Sonotube tubes.

Mounting

You can't overdo it in building a good sturdy mounting for astrophotography. Very few commercial mountings have the attributes necessary. You have a choice between modifying existing equipment (which isn't always possible) and building a mount from scratch. The design or type of mounting used is dependent on the type of telescope and its intended purpose.

Horsehead Nebula and Zeta Orionis Region, 8" f/5 Newtonian, 103a-F, 13 min.

Short-tube compound telescopes function well in fork-type mounts, as do short RFT-type Newtonians. The fork mount has several advantages, one being it doesn't require a counterweight. Another is that the tube cannot hit the pier when the telescope crosses the meridian. One disadvantage is that adding cameras and guidescopes is difficult because of balance problems; another is that unless massively built, they're wobbly.

Cross axis and yoke-type mounts can carry terrific loads, are easy to balance, cross the meridian without hitting, and are very, very stable. They aren't portable, though, but are the best design for a permanent installation.

The most popular mount is the German equatorial. It requires a counterweight and the tube can hit the pier, but it's a relatively portable design.

The following are some design considerations, no matter what type of mounting you use:

Shaft Size There are no published criteria for shaft size that I know of — an engineer could come up with solid recommendations based on the weight and moment of inertia of the telescope, the load path and bearing loading, etc., and I would recommend doubling that result! Realistically, the shafts should be large enough to do the job without being too heavy to affect portability, unless that's not a big factor. I recommend the following rule-of-thumb: make the shaft 1" diameter for each 4" of aperture.

Shafts need not be solid; on the contrary, thick-walled pipe or tubing is readily available and saves a lot of weight. For example, 2" o.d. solid steel shafting weighs 10.7 pounds/foot. 2" o.d., ¼" wall thickness steel tubing weighs 4.7 pounds/foot, a savings in weight of over 6 pounds/foot. And little loss in rigidity, I might add.

Unless you use stainless steel, I

recommend you have the exposed portions of the shafts either cadmium- or chromium-plated. Cadmium is actually superior to chromium as far as protection against rust and corrosion and can be built up on a shaft to control bearing fit.

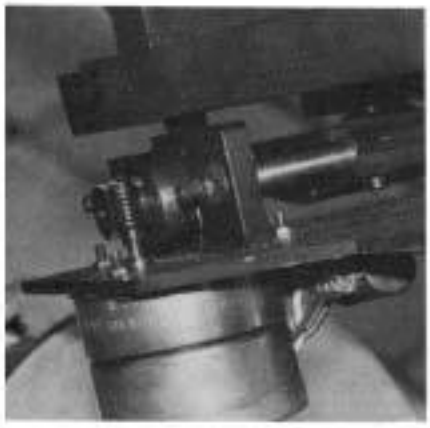
Bearing Type There are many types of bearings that can be used for telescope mounts. Only sleeve or bushing-type bearings are unsuitable, as it is difficult to obtain the proper radial thrust control and maintain it over a long period and under extremes of temperature. (During the recent solar eclipse in Canada, amateur astronomers were advised not to bring telescopes that used close-fitting bushings for bearings. The danger of the bushing contracting a greater amount than the shaft and binding was a real possibility under the extreme low temperatures that were likely to be encountered.)

Ideal bearings would provide both radial and longitudinal thrust control. Tapered roller bearings, commonly found on the wheel bearings of automobiles, are not far from the ideal. The nice feature of these bearings is that you can control the amount of "preload" and thus control the smoothness and inertia of the shaft rotation. These are also among the most common and inexpensive type of bearing, readily available in surplus and salvage outlets.

Pillow block bearings come in various designs to control radial and longitudinal thrust. They are rather expensive when purchased new, but require less machine work on the mount than do tapered roller bearings. Check out the local surplus and salvage outlets — you may find what you want at a good price.

One last word about bearings: don't design and build a mounting around hardware. Acquire the hardware to fit a sound design. It's better to do it right than spend years using a poor mounting.

The PCDA motor with its electromagnetic clutch provides almost instant starting and stopping, but watch out — it draws a lot of current (surge), and if your drive corrector doesn't have enough reserve capacity, it can cause problems in your RA motor when energized. The clearance where the cradle fits the tangent arm is critical — shim as necessary to eliminate any backlash.



RA Drives Few commercially available amateur telescopes are well suited for astrophotography without modifications. This is especially true for right ascension drives. While well-suited for visual applications, and even limited photographic use, most exhibit periodic errors that make extremely accurate guiding either very frustrating or almost impossible. Of the few precision worm wheel drives available for those who are building their own mount or modifying an existing one, those that are good are expensive.

Why a worm wheel? Well, despite their cost and the difficulty in making a good one if you want to make one yourself, a good worm wheel is an incomparably smooth, trouble-free method of moving any "small" telescope under about 48 inches aperture. Worm wheels are very cheap for the precision a good one offers, and once in adjustment they stay in adjustment.

A general rule of thumb for the size of an RA worm wheel drive is: make it the same size as the telescope aperture. For an 8" telescope you want an 8" diameter worm wheel; for a 12" telescope, a 10" to 12" drive.

Declination Drives The alternatives to the worm wheel for RA drives, such as sector gears and threaded rod arrangements, including lead screws and tangent arms, are not entirely satisfactory for long exposure deep-sky photography. They are more than adequate as declination drives. Because we're dealing with a portable instrument (for which precise polar alignment is only a dream), some method of making small declination corrections is necessary.

A major consideration for the declination drive is the drive rate. Most dec. drives run at the same speed as the RA drive, 15 arc-seconds per second of time. This is too fast; half to one-third that rate, say 5 or even 10 arc/sec/sec, allows a much finer control when making small corrections. Remember, you want to be able to guide to a couple of arc-seconds. It also reduces the chance of overshooting and having to reverse direction.

Some astrophotographers prefer to use a manual control knob to make declination corrections, claiming greater control and "feel." The obvious disadvantages, such as remembering which way to turn the knob and not bumping the telescope while feeling for the knob, are factors to be considered before adopting a manual control.

Drive Correctors

In recent years, with the perfection of multitudes of solid state electronic devices, electronic drive correctors have become rather commonplace. Not only can you buy one off the shelf, but plans and schematics are readily available for the D.I.Y. crowd. If you are so inclined, the kits let you really adapt and customize your drive into a very neat and integrated package. My only recommendation for a drive corrector is that you get one that provides at least 8 watts per standard drive motor, or a comfortable margin over the rated draw of bigger motors. Of course, if your declination motor is DC operated, it doesn't count.

Guiders

Another "state of the art" item in telescope electronics is the automatic

guider. These are available in both the single axis (RA only) and dual axis (RA and Dec.) variety. My limited experience with these units indicates that they do work, but would be of maximum benefit in a permanent observatory location where precise tuning of the basic drive rates, polar alignment, etc. can be accomplished. The thought of being able to compose an object in the camera, align the guidescope on a suitable star, start the automatic guider and exposure, and then relax inside the house, especially on a crisp winter's night, sure sounds inviting! In reality, the automatic guider would probably require a certain amount of manual monitoring on a rountine basis during an exposure. Without guiders, well-designed telescopes in permanent locations, when properly aligned and operating smoothly, function almost as if on automatic anyhow. However, the potential is intriguing.

Circles

One tool that's been around for some time is setting circles. It's amazing how few people rely on them as often as they could. For astrophotography in particular, especially when you are photographing intrinsically faint objects, finder scopes of the normal variety are notoriously inadequate. Accurate setting circles are really helpful in finding specific fields or objects in an expedient manner. It really is amazing how many more objects you can see and/or photograph in a given time if you use them.

Guidescope

There are two ways to guide. One is to use an auxiliary eyepiece on a star out of the photographic field, off the optical axis, to track the image formed by the objective. This method is the only way to go with really large telescopes. In small telescopes, space is limited in the focal plane, so a separate telescope, securely attached to the primary telescope, is used for guiding.

What are the minimum requirements for a guidescope? The objective should be 1/12 to 1/15 the focal length (not the aperture!) of the primary telescope's objective. It should have, without any Barlows or focal extenders, a focal length equal to or greater than that of the primary. While guiding, use a magnification at least 5 times the focal length of the primary in inches. For example, with an 8" f/5 primary:

	D	F	mag
primary	8"	40"	
guide	60-80mm	1000mm +	200x

You can see that commonly available 60 mm to 80 mm refractors make a nice guidescope for an 8" f/5 astrographic Newtonian. But a warning: if you use a refractor as a guidescope, the eyepiece will be very close to the ground when you're photographing objects near the zenith, especially if you have a Newtonian on a short equatorial mount. You'll also be about as far from the camera controls as you can get. Because of this, I use a 4¼" f/13 Newtonian for a guidescope. It allows the guide eyepiece to be conveniently and comfortably located near the camera.

Accuracy in Guiding

How far can a star drift off the guide crosshairs and still not be noticeable in the final photograph? There are two basic approaches to this problem: either we can look at if from the point of view of the eye's resolution, or we can estimate the smallest image the system can produce, its net resolution on the film. Let's use an 8" f/5 telescope using 103a-F film as an example and run through both approaches.

Assuming an average visual resolution of 1 minute of arc, the human eye cannot discern the difference between a point and a smeared point .003" long when viewed from a distance of 10". If the print you're going to make is 10x enlargement, then the image blur on the negative can't be larger than .003"/10=.0003". If the telescope used a 40" focal length, then the photograph must be guided to a tolerance of:

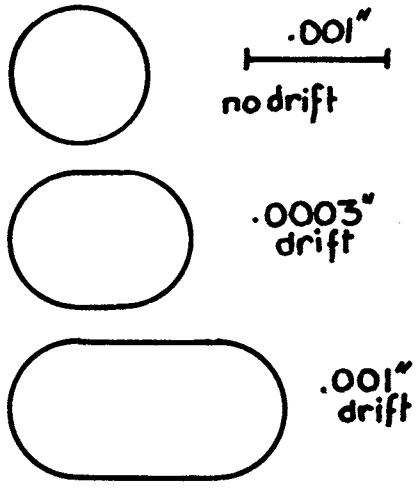
.0003"/40 x 57.3°/radian x 3600 sec/°

or about 1.5 arc-seconds.

Of course, this doesn't mean the star never drifted more than 1.5 arc-sec, but rather that when it did drift, it was returned to a circle having a diameter of 1.5 arc-sec. The times when it drifted would have to be short compared to the total exposure time in order not to record on the film. Fortunately, only the faintest stars produce very small images. The drift in the bright star images is lost in their larger images.

The second approach considers film characteristics. A very fine grain film is capable of recording images as small as 2-3 microns (.0001"-.00015"). Coarse-grained spectroscopic films give images 8 to 10 times larger (.0008"-.0015"). A smaller point of light on the film will still give an image on the order of .001" diameter. With an 8" f/5 telescope, the median .001" on the film represents 5 arc-sec. Therefore, if your guiding is maintained within that tolerance, the image on the film will be as small as the smallest the film can record. Occasional excursions outside the circle are tolerable as along as the duration and amplitude are not excessive. For "completely round and perfect images," guiding should be better by a factor of two or three, or about 1.5 arc-sec.

In general though, tolerances can be exceeded by quite a bit before things get serious. As long as guiding is in the plus or minus 7 arc-sec range, the results will be all right. The smallest images I've been able to measure on my very best photographs are .001" to .0015", or 5 to 7 arc-sec in diameter.



Sources of Guiding Error

Guiding accuracy is dependent on the total system component capability. The periodic error of the RA drive, the amount of flexure, the accuracy of the balance of the telescope, the resolution of the guidescope, the seeing conditions of the atmosphere — all these and more will determine your guiding potential.

Perfectly round images, the ideal, are very difficult to obtain. In fact, many excellent astrophotographs, when closely scrutinized, show image trailing. At normal viewing distances, however, they still show an excellent rendition of many cosmic wonders available and waiting to sit for their portrait.

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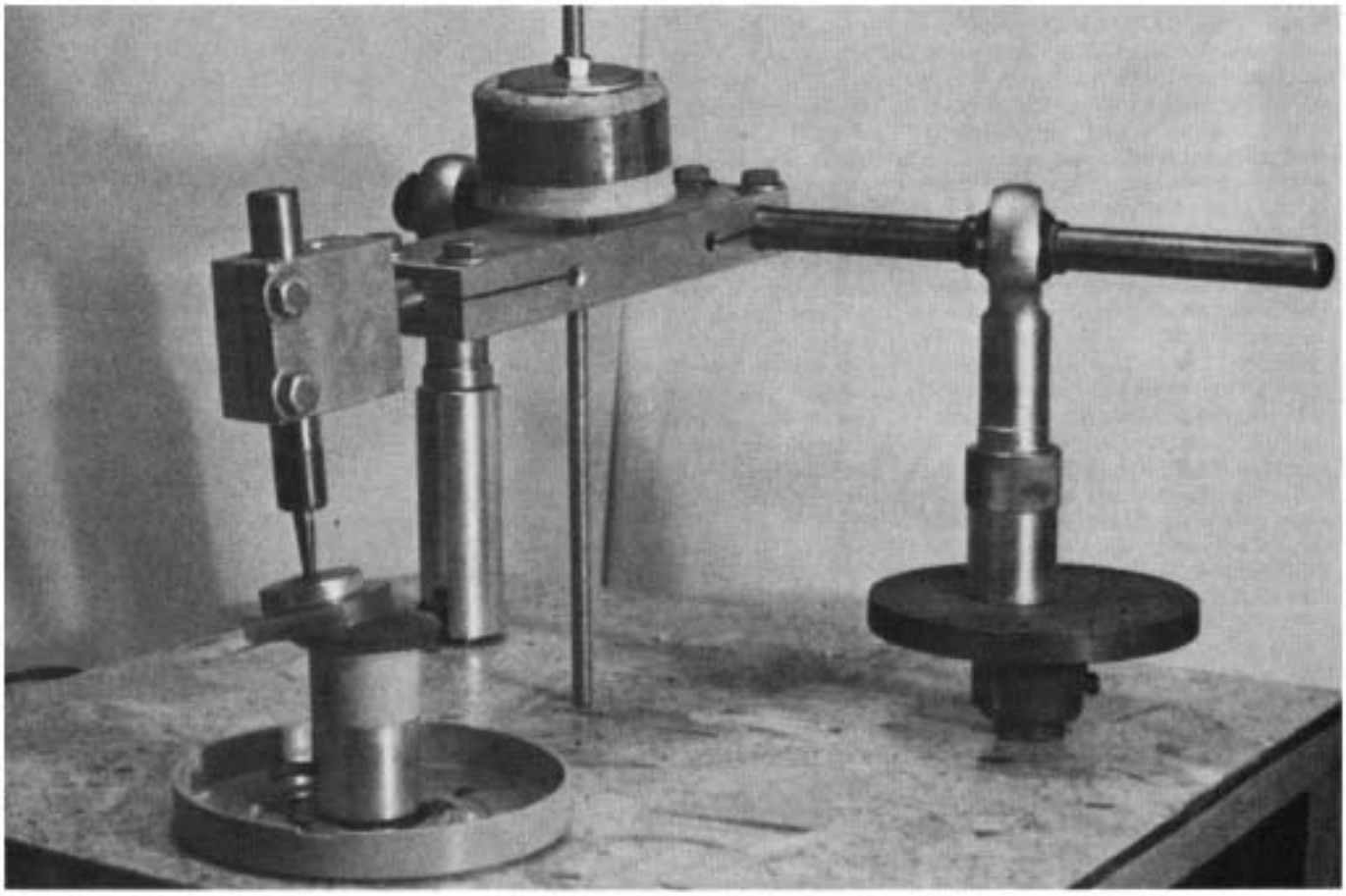
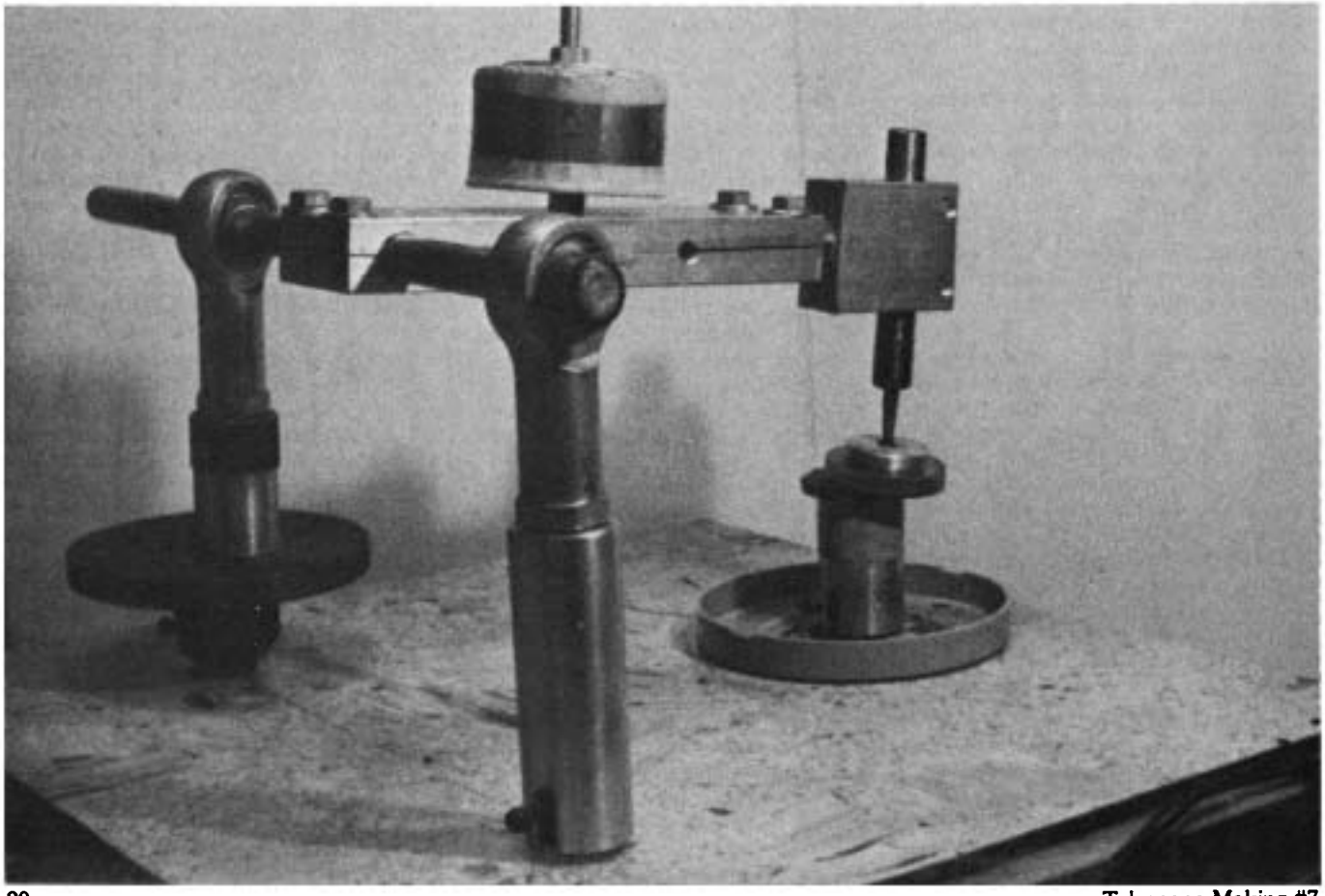
Waldorf, MD 20601





A Portable Polishing Machine

Although most work is usually done by hand in an amateur's workshop, a grinding and polishing machine is both a time and labor saver. It makes the work go faster, and because it doesn't get tired, can get the mirror ground faster. But best of all, it frees the amateur optician for the best part: figuring the final precision surfaces.

My machine is a table top unit. I hope the pictures and descriptions in this article will assist other hobbyists in making a similar piece of equipment for small mirror and lens working. The machine's specs are: a capacity of 6" with three spindles of different speeds. I can set it for rotation rates from 60 r.p.m. to less than 2 r.p.m. The low speed is especially useful in hand figuring of surfaces, while the high speed is used for fast grinding or polishing.

The spindle tops have a standard American Optical taper for dioptric grinding tools that can be purchased in a variety of standard or special curves, and are widely used in industry. If bought in pairs, concave and convex, they can be ground together to the exact radius and kept in condition after use by regrinding. Other uses for these laps are for holding the work and for pitch lap bases. Dioptric laps are made of cast iron and should be slightly warmed before putting pitch laps on them or the pitch is liable not to stick and come off in working.

The three equidistant spindles of Tom Waineo's grinding machine carry the various portions of the driving system, the work spindle with a splash pan to prevent abrasives from getting in the bearings beneath, the eccentric drive, and the pivot spindle. The threaded rod at the center of the arm is the safety which is set at the beginning of work so it just clears the table base during a complete stroke. The safety prevents the pin from damaging the work if the upper piece falls off the unit during work.

One of the largest suppliers of laps and associated equipment is Universal Shellac and Supply Co., 495 West John St., Hicksville, NY 11801. Prices (1975) range from $4.95 for a plano lap to $10.95 for short radii. They also supply adapters with A.O. tapers that thread on machine shafts, pins, points, holders, and many items used in professional shops that are also useful to the hobbyist in his work. There is a minimum purchase charge on all orders, but as they supply pitch, polishing, and grinding materials, it is usually easy to fill the required amount with a purchase of other needed supplies.

Power for the machine is a 1/10 hp geared motor of 30 r.p.m. Since it is geared down by 60 to 1, it develops enough torque for working in spite of the low horsepower of the motor. Variable speed motors are expensive and if you find a less expensive one, they generally develop less power and torque at low speeds.

A pair of three step pulleys, one on the motor and the other on the first spindle, give a choice of 60, 30, and 15 r.p.m. at the first shaft. A pair of pulleys with a belt connects the first spindle to the second with a 3 to 1 reduction and a range of 20 to 5 r.p.m. The second is coupled to the third through a 4 to 1 reduction set of pulleys for a range of 5 to less than 2 r.p.m. The spindles are equidistant from each other, located at the vertexes of an equilateral triangle.

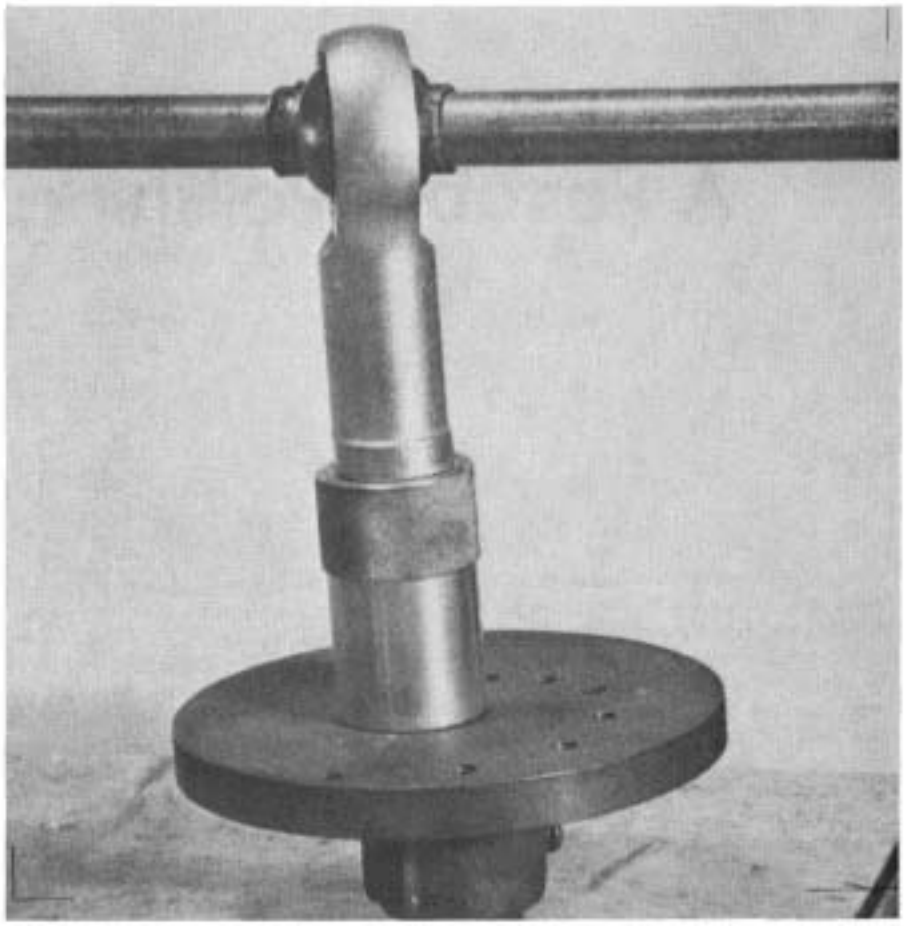
To convert the spindles to a machine operation, a driving mechanism is attached to them. Because of the equidistant arrangement, any spindle can serve one of three functions, work or lap holder, eccentric, or pivot. With this arrangement, a wide choice of speeds are available from a single constant speed motor.

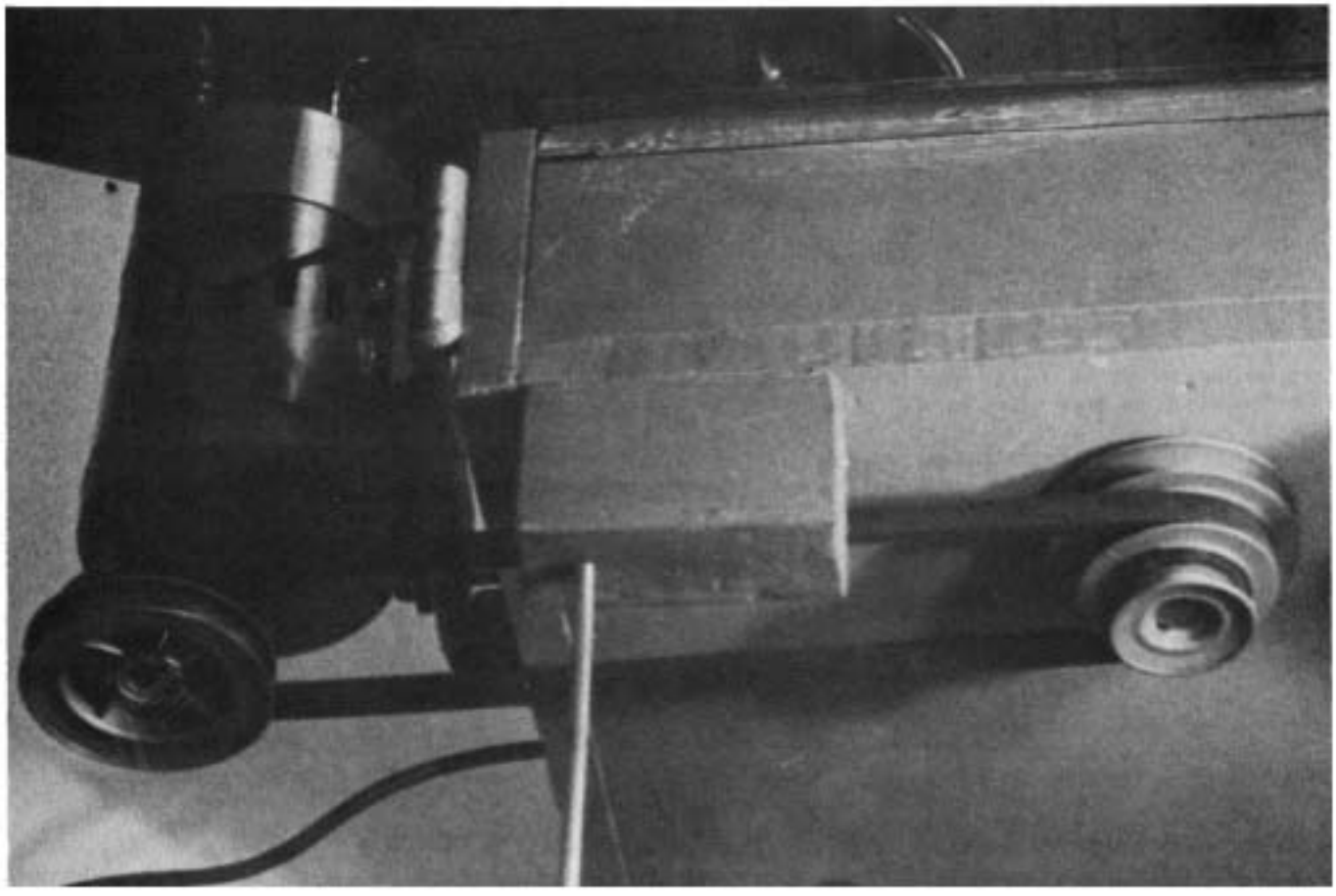
The pivot spindle has a female A.O. taper and supports a rod end in a ball socket with collars on the rod on each side of the rocket restricting any motions laterally in the socket. However, the rod can rotate on its axis to allow the support for the driving pin to be raised and lowered, while the whole assembly can swivel on the base of the ball socket holder.

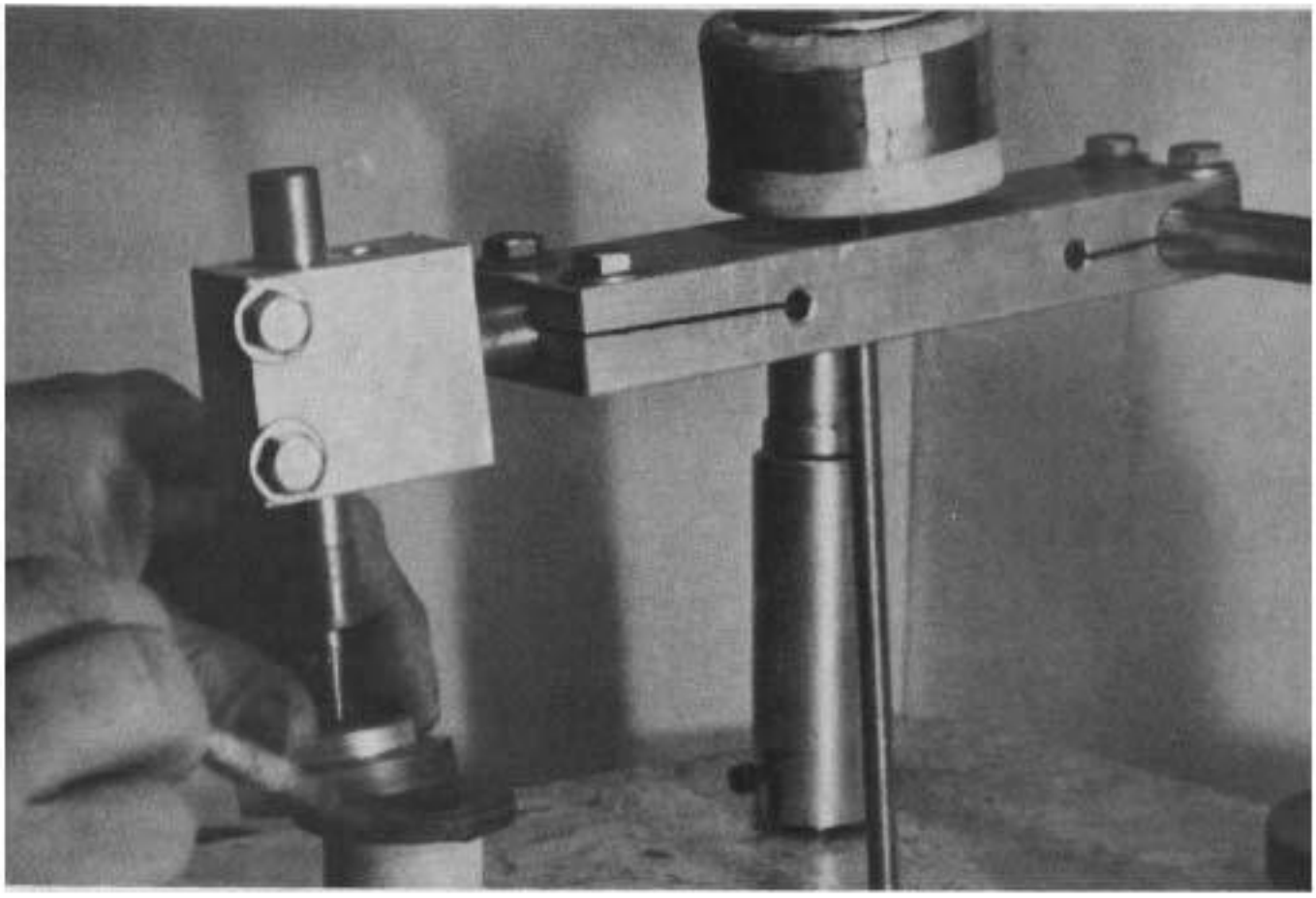
The eccentric spindle has another similar rod end with a threaded bolt in the base. This part is screwed to a flat lap with a set of threaded holes for the control of stroke length. As the photograph shows, the further the hole from the center, the longer the stroke will be. Atop the rod is another ball socket adapter and a rod passes through this ball socket adapter, which has its other end attached at the pivot spindle. The rod is free to rotate and slide in this ball socket bushing providing the stroke to the work piece or lap at the work spindle location.

On the shaft between the pivot and eccentric drive is located the arm that carries the driving pin, in this case, a flat plate with an opening to accept the shaft with locking bolts at the rear. Shifting this arm along the shaft locates the pin position in the stroke, across center to flatten the curve or more to one side to steepen the curve. At the front of the flat arm is an adjustable shaft carrying the driving pin that sets the position of the pin at right angles to the stroke. Note that the driving pin also is adjustable in its height in relation to the workpiece. The arm is made light in weight for small work; weights can be added to increase pressure on large pieces. The driving pin can be a point, or more desirable as it has less wear, it can be a ball. The threaded rod running from the driving arm toward the table top is a safety device in case the work, or lap, jumps off the work spindle (usually due to too dry working conditions between work and tool), allowing the pin ➤

The driving spindle carries a flat metal grinding lap in which are drilled a series of threaded holes at various distances from the center of the axis of the spindle. To keep the lap from rotating on the spindle a setscrew locks it to the shaft. To construct the eccentric a metal post was made in the bottom of which was attached a threaded shaft to fit the holes in the lap plate. As with the pivot spindle an adapter with a ball socket bushing is attached to the post through a vertical shaft engaged in a hole in the top of the post allowing the bushing freedom to swivel on the post as the assembly rotates below it. The work driving rod extending through the ball socket bushing is not restrained but allowed to slide back and forth in the bushing as the unit rotates thereby providing the oscillating motion required in the final grinding stroke at the working spindle.







to drop down and damage the piece attached to the top of the spindle. For each working situation it is adjusted so it just clears the table top during a stroke.

The lap or work is fastened to the last spindle. There are many methods used to hold small optics — blocking pitch, waxes, double-stick tape, and masking tape. I prefer using a holder the same size as the work and attaching it with masking tape. Unless the edge of the glass is very narrow, this method works well and it is easy to attach and remove the glass. The bottom support has an A.O. taper female base to match the male taper at the top of the spindle.

The base of the machine is a wooden box with bearings for the spindles in the top and bottom. The connecting belts are inside and one side of the box is left open for belt inspection. Under the box is the first spindle step pulley. On one side of the box is mounted the motor on a large hinge so the belt can be loosened and moved to another set of pulleys for a speed change. A switch on the side completes the assembly.

A view of the underside of Tom Waineo's machine showing the motor and the belt connections to the first spindle. The other belts and pulleys are boxed in and cannot be seen in this photo but one side of the box is left open so one can reach the other belts for changing speed ratios.

I like using a machine; however, some people feel that a handworker has an advantage over someone working with a machine. Why? Since he can "feel" the action of work between the optics and its tool or lap, it is possible to constantly vary the stroke and pressure to achieve better results.

With a machine, however, I find you do retain "feel." By lightly holding the work as it is being stroked, you can check whether the motion and action is smooth and regular as well as someone working entirely by hand. Once you master the machine, "feel" is just about as good as in handwork.

Machine work is, of course, limited to setting the speed of the spindle, rate of stroke, and pressure. You make small changes in the various settings during work by stopping the machine to introduce a random pattern to eliminate any tendency of zoning. Handwork automatically achieves the random action (or in any case you can introduce it while working without stopping work). Large optical shops have machines that allow the operator to constantly vary the working parameters — but such sophistication is not found on my equipment.

In professional shops very little handwork is needed for spherical work and it is not unusual for a worker to operate four or more machines at a time. Master opticians can finish quality work by machine alone. For small aspheric work, handwork is often much faster than a machine because of its "feel." A variety of spindle speeds are required for handwork to control the cutting action and figuring.

The driving arm of the grinding machine is shown. By loosening the nuts at the rear of the arm, it can be shifted along the driving shaft and so locate the work and its action over various portions of the tool. Similarly, by loosening the front of the arm, the rod there can be shifted at right angles to the driving stroke to further control working action. Bolts in the block containing the driving pin, when loosened, allow the pin to be raised or lowered relative to the working level. It is good working practice to keep the driving arm close to the horizontal if possible.

I don't have a set of drawings on the construction of my machine, but you'll have your own ideas and will modify the general plan anyhow. The idea behind this machine is to make the fabrication of optics by the amateur more of a joy than a chore.

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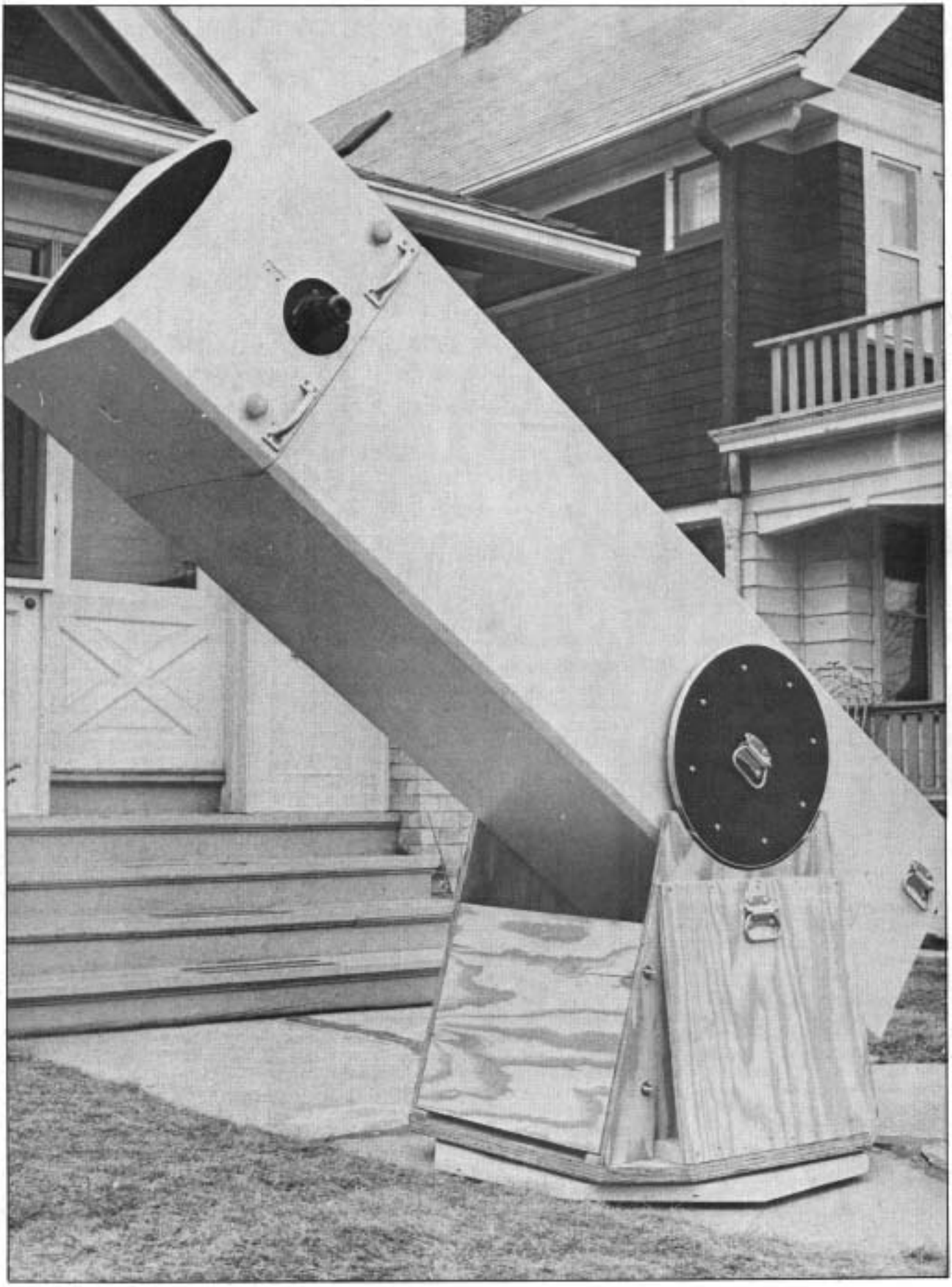


A 20" NEWTONIAN ON AN ALT—AZIMUTH MOUNT

I. Introduction

I'm mainly a deep-sky observer, and I wanted a large telescope. Because I live in the city, unless I found the ideal friendly farmer or good buddy with a lot, the telescope had to be portable. I already owned a semi-portable 12", so any move to a larger telescope had to be a fairly significant step to make it worth the effort.

I finally drew up a loose list of requirements in my head. It ran something like this: a) aperture 20" to 24", since if it's any bigger I'm sure I can't carry it even though I'd really like a 32"; b) Newtonian optical system because it's easy to make and suitable for deep-sky; c) focal ratio around f/5, the best compromise between photographic field and tube length; d) mounting equatorial if at all possible, preferably a yoke because I have lots of experience with them; e) portable on a trailer, by two people, pending the requisite free observatory site becoming available; f) total project cost not to exceed "X" dollars. On the basis of rational consideration of these requirements, I abandoned the whole thing and started thinking about building a 6" refractor.

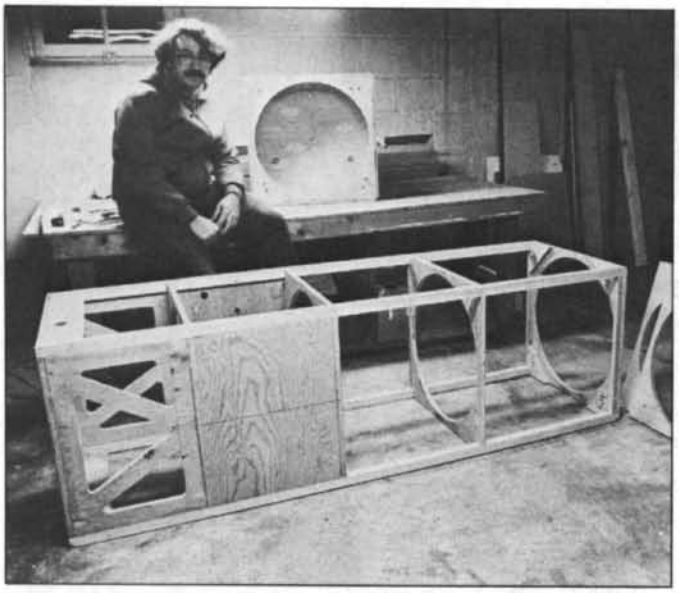
However, I maintained an open mind to any interesting developments and breakthroughs. News kept trickling back from the West Coast about a wonderful alt-azimuth design. I thought that an alt-azimuth might be all right if it had computerized controls but otherwise, forget it. Alt-az is for the birds!

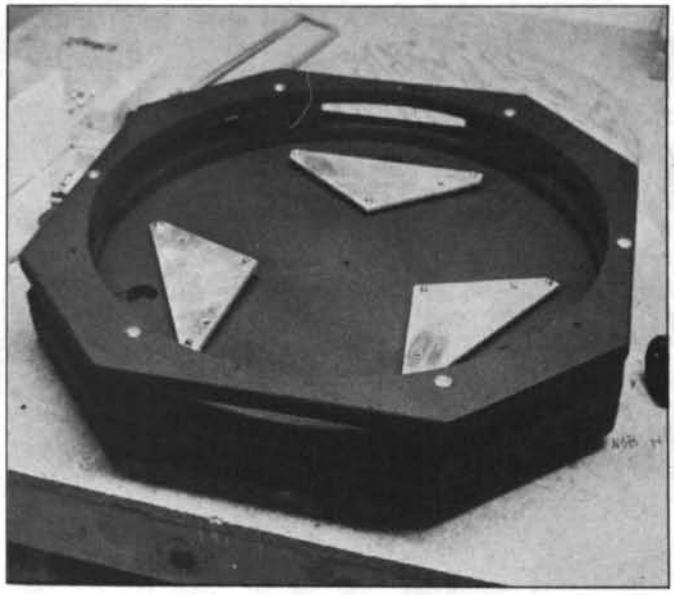
I became seriously interested in Dobsonian telescope mountings at the 1978 Stellafane, when I saw Dennis di Cicco's 16" ATMs of Boston telescope and George Scotten's 12" f/6 telescope -- both on alt-az mountings. They worked well; I was impressed. Objects were easy to find; a simple little push and the telescope followed. I softened my requirement d): an alt-az mount would be good enough for temporary use in any case!

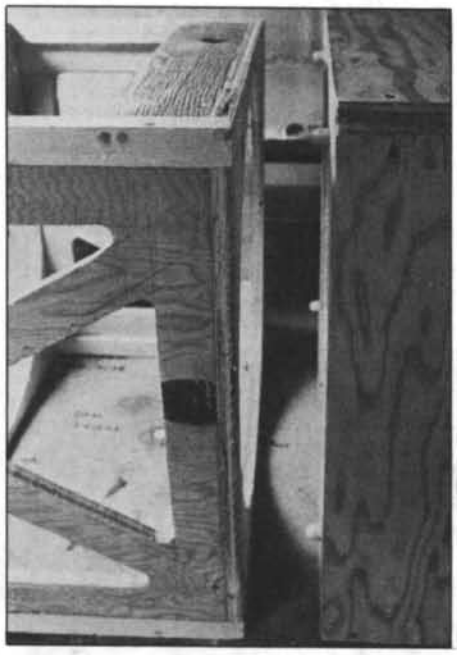
I went home, dug up what little had been published on Dobsonian mountings, and then proceeded to convert my own 12" f/8 over to an alt-azimuth mounting. That mount was a significant variant from a true Dobsonian mounting, but I learned a lot from it. Dennis had embroidered on the basic design when he adapted it, and I went still further. He used a big aircraft bearing in the base. It turned too easily. I made my own bearing with 120 glass marbles running in a channel cut in plywood. It worked pretty well even when the running surfaces washboarded like a dirt road.

I borrowed another idea for my 12" from George Scotten's telescope: using 4" toilet flanges turning on plywood for the altitude bearing. I also noted Scotten's use of devices called "Tyrolia Roll-Ease" on the azimuth. These are gadgets for skis consisting of stainless steel rollers running in a teflon base. Ideal, cheap, pre-made components — but I couldn't find them anywhere I looked. Tyrolia had quit making them.

About six months went by. I checked into the price of blanks. They were expensive. They were also heavy, typically 120 pounds. I thought of all that grinding and polishing. My interest in observing began to outweigh my interest in pushing glass. But the whole idea was beginning to seem slightly feasible, if somewhat half-baked. Then I found that Tyrolia made Roll Disks. I dithered around a month or two more before calling Jim Jacobsen at Coulter Optical to ask delivery times for his 20" f/5 mirrors. He said Corning wasn't making the glass anymore — and soon his supply would be exhausted. Then there would be no more 20" mirrors. I mailed my deposit two days later.







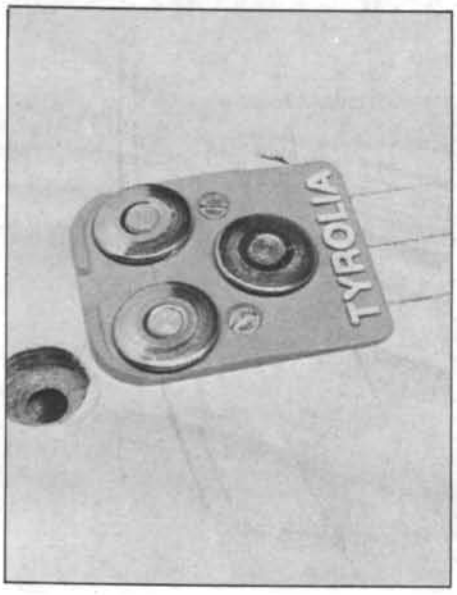
I was now committed to a 20" aperture f/5 telescope. I began to work on the design in earnest. The tube assembly would be over 8' long and 24" to 26" in diameter. Including a 2" thick mirror, about 55 pounds itself, the tube would probably weigh in somewhere between 120 and 300 pounds depending on my choices of materials. My 12" telescope's tube weighed 80 pounds and is hard to handle. Nor did I like the idea of putting the irreplaceable mirror on a trailer behind the car. Too many things could happen — besides the dust.

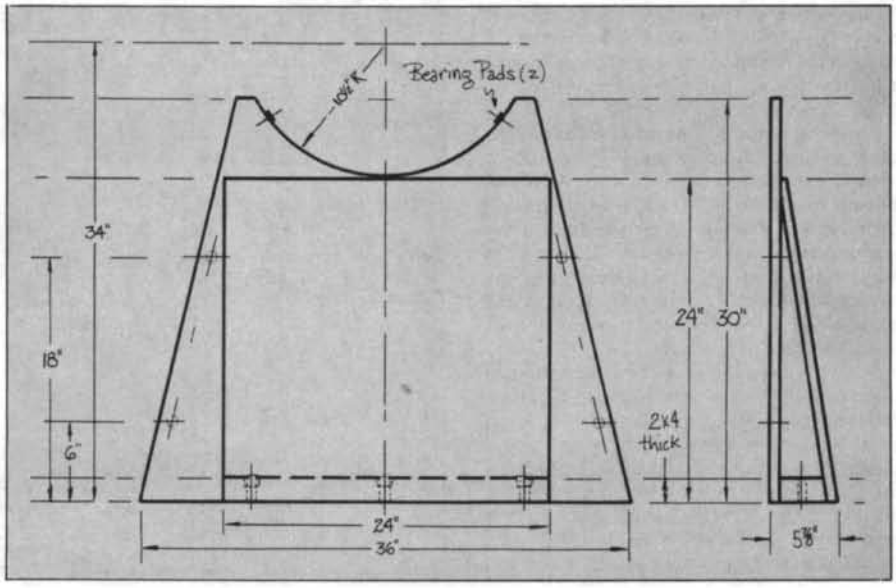
I don't know quite when I hit on the idea of separating the tube into three sections, but it seems obvious in retrospect. If the mirror and its cell were detachable, they could ride inside the car in relative safety. The same goes for the secondary and eyepiece holder assembly. A further advantage: I could build separate upper ends for visual and photographic use. Still another: I could build the telescope indoors because it would fit in my basement. Yet another: Each component individually would weigh less than the whole tube. Portability would be better.

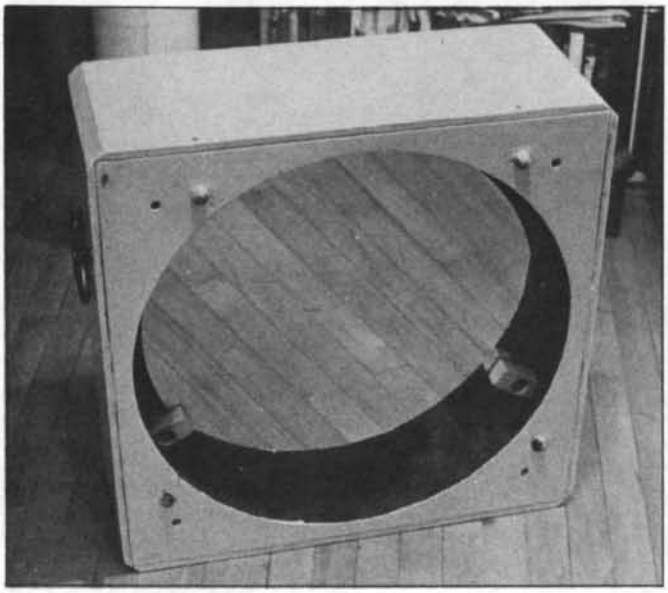
That winter I designed and began work on the tube assemblies. I figured I could hedge until I knew the exact focal length of the mirror, since the total length could be adjusted with the upper end section. The entire center section and everything in the mirror section that didn't depend on the size of the mirror were built by spring. When I went to the Riverside meeting that May, I went intending to learn everything I could about Dobsonian mountings. They are, after all, a West Coast invention.

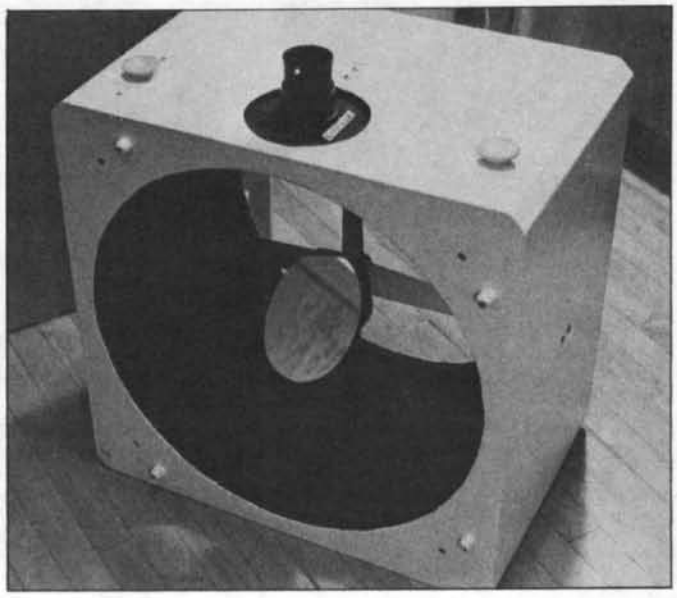
At Riverside I saw and used several Dobsonians, the 16-inchers belonging to Doug Berger and Earl Watts. Their performance was splendid: They turned easily, but not too easily, and high magnifications were no problem at all — fingertip control at its best! I also met Bob Kestner face to face — he's a very able Dobsonian designer — and did a lot of talking about the design.

Mechanically, what impresses me most is









the extreme simplicity of the design. Most important is the material used at the contact faces — and even then there's a wide range of tolerance. Mike Hatcher's 22" Big Box, which the Dobsonian users regarded somewhat distainfully, performs quite admirably despite violating many of the cardinal rules of the Dobsonian genus. Its azimuth bearing consists of six hard rubber casters, and in altitude it turns on a small diameter metal shaft. Overall, it seemed to have too much friction for ideal performance, but even that was no problem at the eyepiece.

As a result of Riverside, I decided that I had done nothing wrong so far, and that I would be somewhat more daring in building my telescope than I might have been otherwise.

The summer passed and I put more effort into TELESCOPE MAKING magazine than I did into any real telescope making efforts. I slowly completed the tube, the mirror section, and the parts for the upper end, then sealed and painted them, all while waiting for the mirror. I waited on starting the mounting. Why? Before beginning the mount, I needed to know the balance point of the tube, and to find that I needed to know the exact weight of the mirror. I had calculated before beginning construction that the tube would balance 31" from the end (by weighing all the wood and hardware I was planning to use and running it through a giant moment-of-inertia equation), but I wasn't going to trust that number and cut up $80 worth of plywood. When the mirror finally arrived, the balance point came out 30.5" from the end. I felt vindicated.

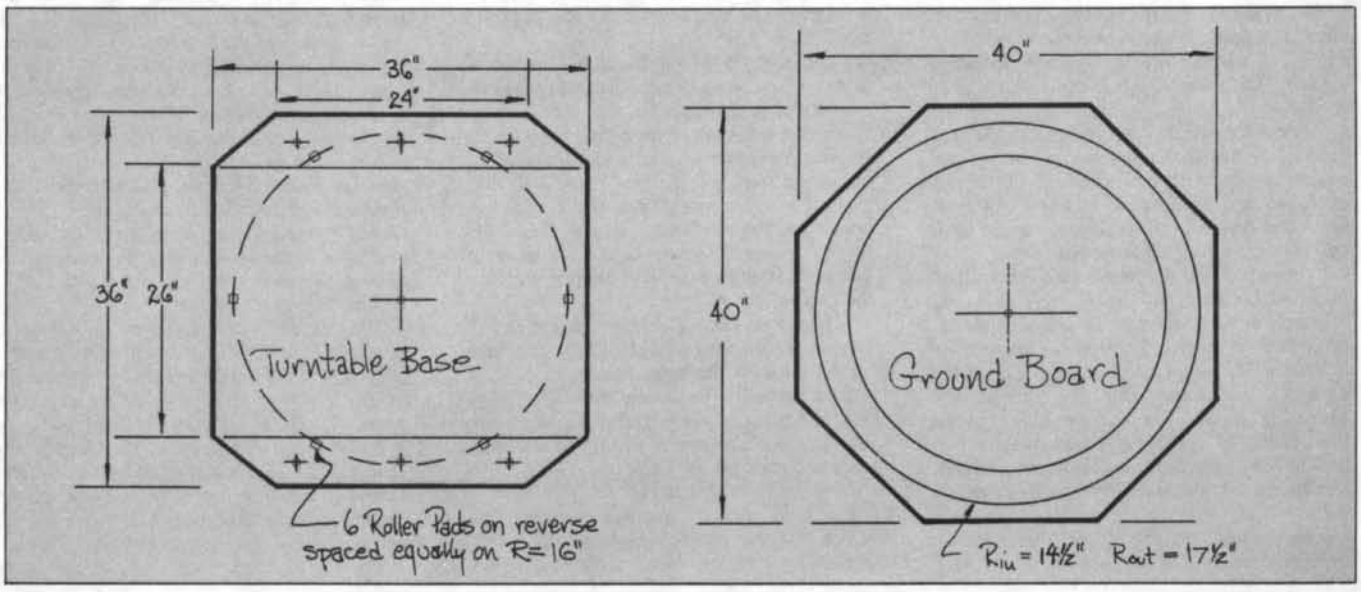
I spent several months thinking about the mount, doodling out lots of ideas — paper telescopes. The solution eluded me. The classical Dobsonian mount for my telescope would stand 3' high and 30" square. It was huge — too big to get in or out of my basement, and probably too big to carry along with the main section of the tube on a small trailer. When I finally hit on the idea, it seemed doubly obvious because I'd already done the same thing with the main tube — I'd build it to disassemble.

After I'd worked out the design of the mount, building it took only a few weeks. The telescope was ready to test in late December. We threw a big party for it on the evening of the winter solstice, but the sky was cloudy. It cleared up two nights later, and the telescope worked beautifully. Since then, I've corrected a few minor problems, added some extra handles for carrying parts of it around, and used it on almost every occasion I could manage (i.e., clear nights when I haven't been working late on TM, ASTRONOMY, or sick with the flu).

II. The Technical Details

Design

In the real world of machine design, the deformations of structures must be taken into account. There are two principal deformations to design out in telescopes: 1) the sagging or bending of the tube, and 2) deformation and oscillation in the mounting. In coping with deformation, the designer has two routes open to him: he may attempt to make the structure very rigid, or he may take



flexing into account and even use it.

Machined mountings for small telescopes (such as the superb mountings Californian Bill Schaeffer builds in his home) are usually designed for extreme rigidity. It's a very practical approach, and the thick cross sections don't weigh much when they're going to support a 6" to 12" telescope. The stiff mount has a high resonant frequency and vibrations in the system die out quickly. At the other extreme, the engineers of the 200" telescope could not eliminate tube flexure, so they designed both ends of the tube to sag equally and remain parallel.

I took both approaches: I tried to build an extremely rigid tube, and tried to use the (inevitable) deformations in the mounting.

A telescope tube is what an engineering book calls a *box girder*. The cross section determines the stiffness of the beam (you can get this from any text on the strength of materials — it involves calculating a quantity called the *moment of inertia*). Even without exhaustive calculations, it's obvious that you can maximize the rigidity of a beam by distributing its mass as far from the axis as possible — into a thin ring or box. (This is why hollow polar axes work so well.) This sounds ideal for a telescope tube, but there's a catch: the cross section mustn't change on being loaded. Thin tubes, as we all know, squash out of shape.

Placing bulkheads or internal stiffeners inside a thin-walled cross section eliminates much of the change in shape. Look at airplanes and canoes for examples of this. Even one ring at each end of a telescope tube can eliminate many flexure problems.

I chose to build my telescope's tube out of plywood because it's cheap, easy to work, relatively light, and has low thermal capacity. Plywood, in turn, dictated a square or hexagonal cross section. I chose square for ease of construction. The tube consists of a skin of ⅜" plywood, which provides most of the rigidity of the tube, supported by five bulkheads which keep the skin from deforming out of shape. The tube is extremely stiff.

The mount, on the other hand, allows deformations, and in fact depends on them for proper operation. Alt-az telescopes often have a base resting on three pads. Two uprights (the side boards) support the telescope's altitude trunnions. When the telescope is turned, one side board is pulled forward and the other pushed backward. The sideboards exert a torque on the base, and it rotates. It also twists slightly. When the observer stops pushing, the base untwists, and the telescope rotates back through a small angle. This is *backlash*.

The beauty of the Dobsonian design is that 1) the teflon-on-formica bearing has a very low coefficient of friction which means the push produces a very small amount of twist, and 2) it's easy to make the base very stiff and, thereby, to minimize the twist. In light Dobsonians up to 16", this seems to be entirely negligible.

As the telescope becomes larger and heavier, the frictional forces and the cross section necessary to make the base rigid both increase. My experience in converting my rather heavy 12" f/8 Newtonian to a Dobsonian with unusually tall side boards convinced me that a rigid base for a 20" would require four or more layers of ¾" plywood weighing over 100 pounds — too much for portability.

I decided, therefore, to allow the base to twist and to use more support points than the conventional three. Although a three-point support is necessary with a rigid base (so the telescope won't rock like a four-legged table on an uneven floor), if the base is flexible, placing two support points under each side board eliminates flexure in the base. The telescope won't rock because the base will flex so that all four points of support rest on the ground board.

(Those long folding tables familiar to church basement functions sit with all four feet firmly on the floor for the same reason.)

So I made the base only two layers of ¾" plywood thick. It has turned out to work very well — there is no backlash and the telescope does not rock on its supports.

Structure

The tube consists of three sections: the main tube (which is just a big box), the mirror section, and the upper end (with the diagonal and eyepiece). To assemble the telescope, I needed ⅜" machine bolts or threaded rods entering threaded metal inserts (called "tee-nuts") in the main tube. Tee-nuts serve very well for this purpose. You can find them in large hardware stores.

The framework of the main tube consists of four 76" long square milled wood (1⅝" ballisters) doweled, glued, and screwed to the five ¾" plywood bulkheads. I used dowels for extremely high joint strength against the violent jolts and jars a portable telescope will inevitably experience over the years, and screws and glue for tight structure. Each plywood bulkhead is 24" square with a 22" diameter cutout. It would have been desirable to make the tube bigger, but this would have greatly increased the number of sheets of plywood used. By choosing the wood for straightness and working carefully, everything came out square and within 1/16" of the proper dimensions.

Next I cut and inserted four strengthening panels of ¾" plywood between the trunnions and the end where the mirror cell would be attached. These are doweled, glued, and screwed in. The attachment points for the bolts that hold the mirror section and upper end on are two thicknesses of ¾" plywood, doweled to the corner beams. The corner beams serve as anchor points for the rigid skin of the telescope. Three of the panels are held by 60 woodscrews (each!) and glue; the fourth is not glued for access. The corners of the tube are rounded for two practical reasons: if they aren't rounded, the panels would have to be wider than 24" (requiring too much wood); and square corners would soon be banged off anyway. In retrospect, the tube is overbuilt. It weighs 95 pounds.

The altitude trunnions are 20" diameter disks of ¾" plywood each wrapped with a strip of ⅛" x ¾" aluminum bar stock. It is attached to the disk by countersunk wood screws every 4". Each trunnion is held by eight machine bolts entering tee-nuts inside the tube. Eight ¾" plywood circles 2½" in diameter hold the trunnion away from the tube for clearance in the mounting. The trunnions can be removed by removing the bolts.

The mirror section serves as a protective

box for the mirror as well as the mirror's cell, so I overbuilt it also. The bolts that attach the mirror section to the main tube pass through it from the rear, so the cell parts are compressed when attached.

The mirror cell consists of a 1½" thick base with rings of ¾" plywood spaced 1⅝" apart by six wooden blocks, enclosing the mirror. Three triangles of ¼" aluminum plate balancing on the heads of acorn nuts make up a nine-point longitudinal suspension. Radially the mirror rests on two felt pads 60° apart, but there is space in the cell to put in a sling if necessary. Three thick wood clips retain the mirror. The free travel allowed for the mirror is about 1/32". With the mirror in it, this section weighs 110 pounds, but is relatively easy to carry because it has handles on the sides.

The cell is held in the mirror section by three pairs of ⅜" push-pull bolts. The sides of the cell touch the inside walls of the tube section. If the section is dropped, the cell presumably won't rip free. It'll stop at the same time the outer box does — same theory as automobile seat belts.

The upper end was built only after I had received the mirror. It is 16" long, with two bulkheads, but is otherwise built like the main tube. I bought the "research grade" spider, 4.5" diagonal holder, and 2" helical focuser from Kenneth Novak & Co. They perform well. I plan to build several alternate upper ends for different purposes. The upper end assembly weighs 20 pounds.

The tube sections are assembled with ⅜" machine bolts. Locating pins made of ¾" dowel rod roughly 1" long prevent lateral displacements larger than 1/32" when the parts are brought together. The locating pins protrude, in both cases, from the detachable tube sections. The tee-nut fasteners are in the main tube. I took extra care that the rear bulkhead in the main tube (which carries the weight of the mirror) is firmly tied into the tube with dowels, screws, and glue.

The mount has five major parts which are assembled with ⅜" machine bolts. There is a ground board, a base, two side boards, and a front board.

The side boards on the mounting are detachable from the base. Each consists of two plywood sheets that form a thin triangle. The base of the triangle is a 2 x 4 with three ⅜" tee-nuts to receive bolts from the base. Each side board weighs 30 pounds. Handles make them easy to carry. Each of the four altitude bearings is a 1⅛" diameter nylon floor caster with the soft grey plastic lid of a Kodak film can resting on it. This soft material works very well against the aluminum trunnion.

The front board keeps the side boards properly spaced and parallel to each other. Although the mount works without it, it improves the stability of the side boards. It is 19" high by 26" wide, made of ¾" plywood. Two ⅜" threaded steel rods 29" long, fitted with wing nuts, clamp it tightly between the side boards.

The base is an irregular octagon 36" across, and is made of two layers of ¾" plywood glued and screwed together. The side boards bolt to it from the bottom; the heads of the bolts are recessed and bear on fender washers glued into the hole. I used a socket wrench for running them in. The base weighs 50 pounds.

The base turns on six Tyrolia Roll Disks, a ski component consisting of a molded teflon base with three 1" diameter circular bosses on its face. A steel disk with crimped edges fits over each boss and is free to turn on it. The Roll Disks carry the full weight of the telescope and mount with no trouble, and run on a masonite track on the ground board. Four of them are under the ends of the side boards to prevent twisting of the base; the other two are "there for the sake of symmetry," and could probably be eliminated. Roll Disks cost about $4 each, and don't wear or get dirty like teflon squares. Their performance characteristics probably aren't quite as good, but it would be very easy to switch to teflon.

Finally, the ground board is a regular octagon 40" across, made of two sheets of ¾" plywood glued and nailed together, with a 37" o.d. ⅛" thick masonite ring 3" wide glued to its face. At its center, I've inset a bushing to fit the removable ½" piece of bar stock the base pivots around. The ground board weighs 60 pounds.

All the wooden parts are sealed with XIM Flash Bond #400 Clear Primer and Sealer (XIM Products, Westlake, OH 44145) which is great stuff. The outside of the tube is painted with Mastercraft Gloss Oil House and Trim paint, the interior with #412 flat black Rust-Oleum.

Optics

The optics are those of a conventional 20" f/5 Newtonian. Coulter Optical made the mirror. It is 20.5" in diameter, 2.1" thick, and has a focal length of 99.1". It weighs 53 pounds. The minor axis of the diagonal is 4.5" — rather oversize to allow for a fully illuminated photographic field.

I initially had reservations about disassembling the tube because I thought it might cause an alignment problem. However, it does not. The error introduced in attaching the cell should not exceed 0.25 mm across the width of the mating faces. This is simply a matter of wiping the faces before joining them. At any rate, experience shows that alignment is not lost from night to night.

III. Operation

The telescope is easier to handle and assemble than I had expected it to be. I assumed that it would take two moderately strong people about twenty minutes; instead, one strong person and a lightweight helper (my wife) can set up the telescope in about ten minutes. So far, I don't have a trailer to carry the telescope into dark country skies, but have stored the telescope on a porch and carried it into the yard for operation.

Set-up goes as follows: Place the ground board on the ground and stomp on it to get it level and solidly seated. Carry the can of bolts, the socket wrench, the base, and the side boards out. Bolt the side boards on, then flip the base onto the ground board. Center it and drop in the king pin. Slide in the threaded rods, drop into the front board, and tighten the wing nuts on the rods. It takes two to carry the main tube over to the mount. The stronger person lifts the end of the tube high enough and lowers it in the mount. Place the upper end under the rear of the tube. Carry the mirror cell out, lift it and rest it on the upper end. The weaker person can lift the front of the tube so the holes in the tube are at the same height as the locating pins. The cell is then slid forward and bolted on. The front of

the tube is pushed down to release the upper end, which is carried around and bolted to the front of the main tube. There are a total of sixteen ⅜" bolts to install: six in the base, the two rods for the front board, and four each in the cell and upper end.

Taking the tube apart seems to be an unqualified success, not only from the handling standpoint, but for transporting it as well. If a minor trailer accident does happen, the replaceable sections — the base parts and main tube which are riding on the trailer — are most likely to be damaged. The optics ride in the car with the observers.

The assembled tube weighs 225 pounds, and is almost impossible for two people to handle. The mount weighs 130 pounds, but is pretty easy for two people to carry assembled because of the handles on its sides. It's almost magical once the instrument is assembled — it glides so smoothly around and up and down, and its weight seems to dissapear. When the tube is pointed up at a 45° angle, it takes about 10 pounds force to make the telescope begin to slide smoothly over in azimuth, and about 15 pounds force to make it move in altitude. I find this amount of force about right, and there is no problem with the telescope moving in the wind. I can follow objects with a 4 mm eyepiece (600x) with little difficulty.

At 80x, with a 32 mm eyepiece, the images are brilliant and sharp. I was able to see the backlit side of Saturn's ring system in January at 250x, but a bout with the flu and the poor weather in early March prevented my seeing the ring plane passage. The Orion Nebula and other deep-sky objects are impressive even in the brightly lit sky over my house. A 20" telescope is far more sensitive to seeing and atmospheric turbulence than smaller telescopes — it seems to be something you've got to accept in this climate.

Almost every time I have it out, passers-by stop to look. "What's that?" they say, eyeing the 10-foot-high yellow box. "Is it a telescope?" It's always fun to let them look.

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■

zeroing in with a

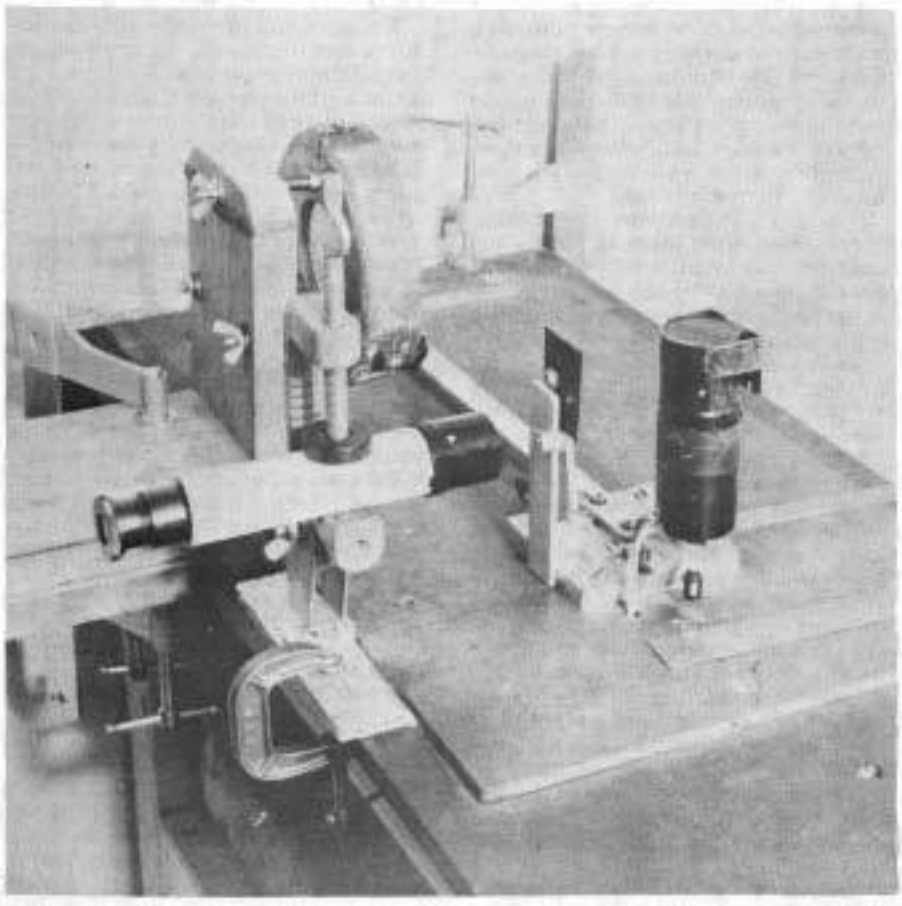
How do you hold a 966-inch radius of curvature on a concave mirror while working in a 520-inch basement room? Holding it turns out to be no problem, but catching it may be.

Ingredients to a solution: An extra steady knife-edge test stand, a 5-8 power finder scope back-focused, mirror cells like those in telescopes, a good aluminized flat, and lots and lots of PATIENCE.

The flat meant I could fold the beam across the basement, but there was no way I could get more than 20" behind the knife-edge for my eye, and 24" back of the final position of the shallow concave mirror to catch the first indications of a shortening radius. (Such mirrors shorten surprisingly fast in the polishing stages and have to be finish ground on the long side.)

The challenge had to be met because the 6" Kutter Tri-Schiefspiegler system I was building calls for a spherical tertiary of 966-inch radius, used as a correcting diagonal in the TCT design.

Check off: I had a proven test stand that was steady, plus plenty of C-clamps, an extra finder, mirror cells made specifically for the projected Kutter, a coated best-of-three flat I had recently finished while waiting for a new telescope making project to show up, and I thought I had the patience to finish the project.



I clamped the 6" flat (in a cell) to a temporary stand on a table 482" from the tester light on the same horizontal plane. I turned and tilted it until a beam from a small high-intensity desk lamp held in front of the light slit position was reflected back near where the new mirror would be placed. The cell of the mirror under test and its stand were clamped on an extension board clamped to the tester table. This provided the extra 24 inches.

Even though an inch larger than specifications, I chose readily available 4¼" blanks. First I ground them approximately flat, alternating them with a larger plate glass surface as in regular procedures for flats using 220 and 320 silicon carbide. Then the two disks were ground on each other alternating on top with #500 silicon carbide for about 6 wets to remove the #320 pits. Next, the best disk was selected and marked "C" for the concave and lightly worked on top of the other (tool) disk with #500 for 7 wets, 14 micron aluminum oxide for 3 wets, and 5 micron for 3 wets.

I put a temporary lap on a 4¼" cast plaster disk, and pressed it with mat and netting. This was used for flash polishing until the tool could be freed after the radius was established.

The concave was cold pressed on the lap and given a flash polish of 5 to 10 minutes with cerium oxide — just enough to get some reflection. (I also used some glycerin-water on the ground face to brighten the reflection while first lining it up in the cell and tilting it.) A good measure of my supply of patience was used up in this first confrontation. By bobbing my head around and waving the small bright light beamed from the portable lamp, I finally located the beam and held it long enough to "tune up" the two surfaces into rough alignment.

Once I had it, I then had to decide whether this spot of light in my eye

long radius mirror

showed that it was inside or outside of the radius for the mirror being tested. Horizontal motion of my head or the light source (lamp or flashlight) produced a subtle movement of the spot across the mirror face. If it's in the same direction, the eye is inside the cone of light returned from the mirror, that is, the center of curvature is back of the eye, and the radius is too long. If it's in the opposite direction, the eye is outside, and the radius is short.

Well, on the first try the mirror came out way short of the necessary radius, so back to the grinding board. With the tool on top, I did 3 wets of 500, 2 wets of 14, 2 wets of 5, then a cold press, 10 minute flash polish, and tested. This time the center of curvature was outside the room with no way to guess how much. Then with 3 more cycles of only 5 micron, etc., with mirror on top, a disk of light could be picked up and a handheld knife-edge proved that the center was back in the room — but too close to begin more polishing. Once more I ground, with the tool on top and 5 micron grit, until the polish was worn off quite evenly. At last the center was estimated at just outside the back wall, and there was a good chance that the serious polishing could start.

I made a new lap which was made on the glass tool and worked the mirror on top by hand until the polish was coming up pretty good. Shortening was taking place reasonably and a disk of light was developing. The scope was lined up behind the knife-edge and a wide slit could be used.

As the polishing progressed, it appeared that a hyperbolic shadow was developing, so I added figuring to the polishing job, working to remove the area around the faint hole. The lap was cold pressed after each spell of work and the spherical figure was nearly restored by the time the radius was reduced to 25" on the long side.

I now changed to black rouge and a machine polisher with short, narrow strokes. Polishing for at least twenty minutes a period to start and gradually shortening the time to 10 minute spells, testing, correcting as necessary, cold pressing and working with the mirror top brought the shape to a good sphere and edge. When the radius was brought to 5" long, the lap was cold pressed by the mirror every 10 minutes or less of polishing and plenty of time was given for the mirror to stabilize to room temperature before null testing. This last step was slow but satisfying; patience was paying off. I put seven hours total polishing time on the glass — two hours on the last 13" of radius.

I got a null with the figure as the radius dropped a quarter inch short in the last periods of polishing — just 2 minutes work. So I cold pressed and did a minute more with lap on top, and it tested a quarter inch long. Another minute with the mirror on top brought the radius as close as could be measured to what was called for.

The mirror was placed on the tester stand at least 36 times; the tester came through and so did my patience.

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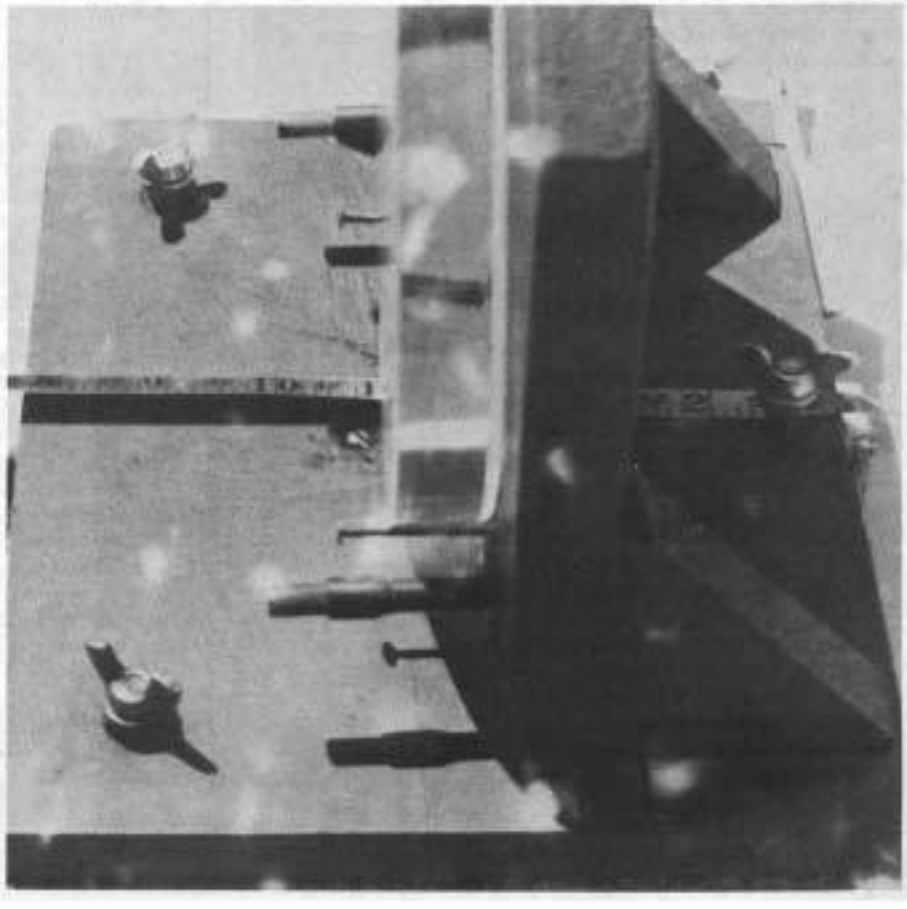

Adjusting a 10" Schiefspiegler

The article on my 10" Schiefspiegler in TM #4 (page 8) did not show in enough detail how the corrector lens is aligned. Here's how it's done:

The tube housing for the corrector-lens cell has two holes drilled opposite each other to pivot the cell. Elongate them laterally and longitudinally to provide room for back and forth and vertical adjustment.

For optimum results, the pivot holes with their elongated slots must be carefully drilled so they are precisely opposite each other. When the pivot screw without washer/nut is positioned on one side, the other side should correspond. Use a cardboard jig the i.d. of the tube and the proper angle of tilt for initially setting the lens angle.

Residual color is eliminated by moving the lens cell assembly up or down and/or laterally (one side at a time) along the elongated slot in the tube. Experimentation is necessary to achieve the best result.

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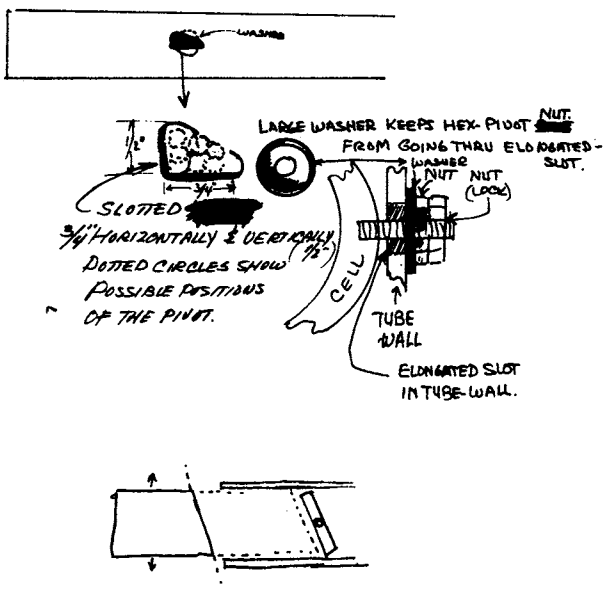
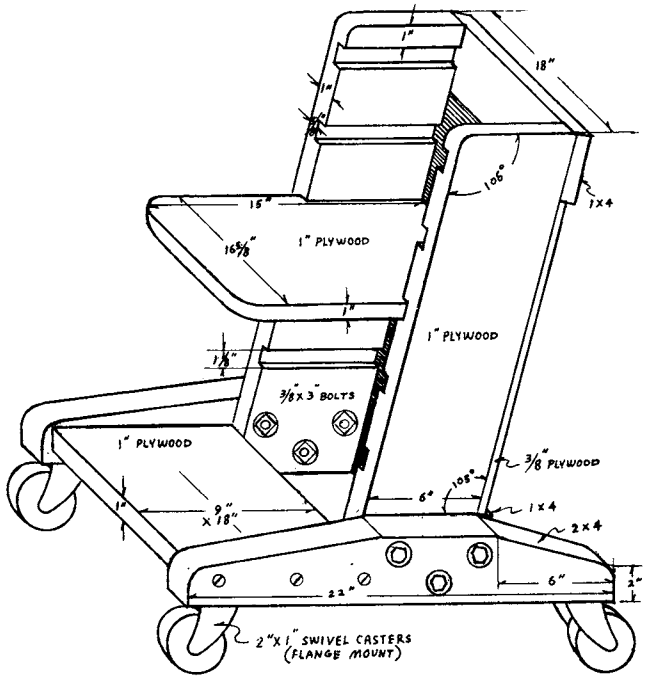


A Handy Chair for Observing



I am especially proud of the Observer's Chair that I designed and made. With each passing year I attach more and more value to this comfortable piece of equipment.

I have given copies of my plans to many other amateurs to whom I know and correspond with here and in other countries. Many have built their own, and have expressed their pleasure in its application.

The basic dimensions are given on the drawing. Many of these may be changed to fit the individuals own personal needs and desires; such as, the number of seat slots, overall height of chair, size of seat, and so forth. All fittings and joints should be glued and secured with screws or bolts. This chair actually requires very little lumber — you can get it at most lumber yards as inexpensive scrap lumber.

I have only shown 5 seat slots in the drawing to simpify it. Actually, I have 9.

Refinements can be added, limited only by your imagination. On my chair, I have upholstered the seat, mounted plywood, flash light and eyepiece holders on the sides, installed a spring-loaded, hinge up, metal map shelf, which attaches to the top of the back, binocular holders, etc. I have also attached a two-hour bell timer which I use for timing long exposures. It emits a gentle "ding" when the pre-set time has run out.

I took the chair sides to a local woodwork shop to have the seat slots routed out. This cost me one dollar.

Choice of the caster wheel size will be governed by the surface on which the chair will be used.

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Observing through a Roof Hatch

My observatory is 12′ wide by 13′ long. It was built as part tool shed, part observatory. In the roof is a hatch which opens and closes —that's the observatory part. The hatch is 24″ x 12″. Through it you can see the celestial equator, where the Moon and planets pass through, and the ecliptic. I have always wanted an observatory for my work and pleasure after a hard day's work. I can go out on a clear night and stay out for hours.

I have the telescope resting almost against the hatch. The hatch is far more convenient than lugging the telescope up my stairs every night to show people. I started looking for a company that makes a good shed, then adapted it for astronomical work. It took a few weeks, but it's worth its weight in gold for anyone who has a telescope.

Larry Angelow
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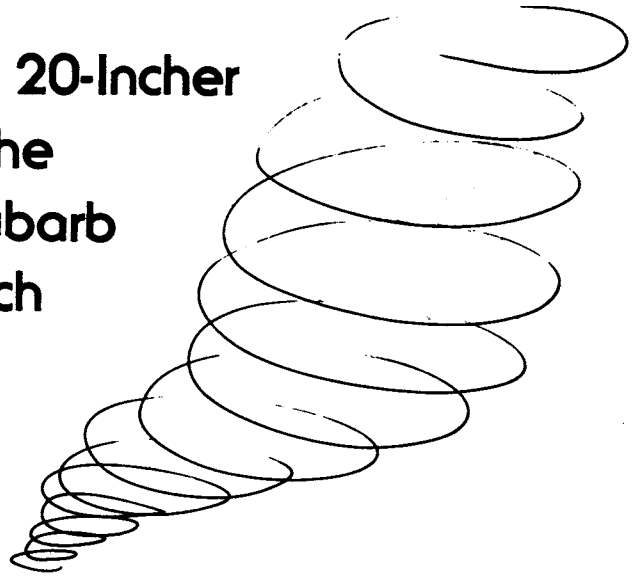
The 20-Incher in the Rhubarb Patch



Well, friends, it seems that Monday evening, June 4th — the day after the convention star party — the Chleborad farm where MEAC observatory is located was visited by this little tornado. Actually, it didn't touch down, just unscrewed some trees nearby, blew the chimney off Chleborad's house, and clobbered the 20″ scope. The optics were not in the tube, so they were not damaged, and actually the tube assembly sustained only minor damage, but it sure looked forlorn lying in the remains of Mrs. Chleborad's rhubarb patch belly-up and mired in the Missouri mud.

There was no damage to the club buildings (other than some water leakage) but a storage cabinet was torn loose and blew all the way down to the house leaving a trail of screws, nails, broken glass, and electrical stuff. It came to rest on Mrs. C's decorative fountain which it smashed to little pieces. What a bummer; perhaps it was insured.

But, thank goodness, we had the convention star party before such an event so everyone who wanted to got to use the 20″. As an aside, I think it's a tribute to the construction skills of Rick Johnson, who was primarily responsible for the buildings we have, that there was zero damage to our facility in the face of 75-100 mph winds. Nice goin' Rick!

from *Nova News* (Midland Empire Astronomy Club, Inc.)

A Shelter from Streetlights

To me the most annoying aspect of light pollution is not sky fog. Even in light sky, you can still do quite a bit of useful and interesting observing. The real problem is the annoyance and loss of night vision due to neighborhood streetlights, porch lights, and car lights. The solution to this problem is an observing shelter of some kind — best of all an observatory. However, since my observing site is in my front yard, I didn't want to erect a permanent observatory because it would be unsightly and expensive.

I have, however, devised a solution which has been a boon to my observing, which I want to share with other amateurs who may have similar problems. I made a rectangular cloth curtain, eight feet on a side, which hangs from four support poles, enclosing my telescope and me on three sides. The fourth side could also be enclosed, but it wasn't necessary for me. It was designed to be set up or removed in five minutes, and to leave no trace when removed.

To make holes in the ground for the support poles, I buried four 2½′ vertical sections of 1½″ ABS plumbing pipe, with screw caps on top to prevent debris from falling down the pipes when they're not in use. The pipe caps are just below grass level, not noticeable, and can be mowed over.

The curtain support poles are made of 8-foot lengths of 1¼″ electrical metallic tubing (EMT). The poles have eye-bolts at the top to hang the curtain from. 1¼″ EMT is available at electrical supply dealers. It is lightweight, strong, and cheaper than pipe.

When I get ready to observe, I unscrew the caps from the buried ABS pipe and drop the support poles down the holes, making an 8-foot square of four 5½′ supports.

The cloth curtain is suspended from a heavy-duty metal clothesline cable covered with plastic sleeving. It is sewed into the upper edge of the cloth curtain and comes out through plastic grommets at the corners. Grommets must be used, or the cloth will tear. I hook the cable over the eye bolts on the poles, and use turnbuckles at both ends to adjust tension.

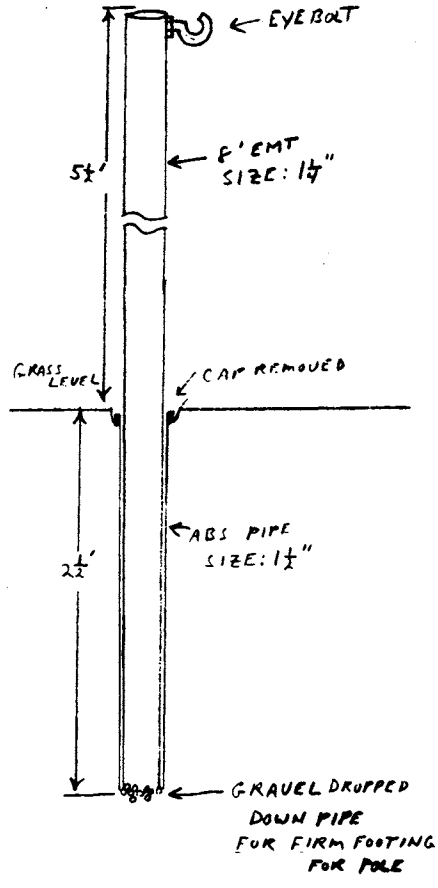
The bottom of the curtain is then tied to the poles with cords attached to grommets in the curtain. This prevents it from flapping in the wind, and it can be used in fairly strong breezes.

The shelter cost about $50 to make. It goes up and down rapidly, and as an extra benefit, provides protection from the wind as well as the lights. It will work well with refractors or Cassegrain types, but probably would lose its value with Newtonians over 6″, due to the high eyepiece position.

Just a few pointers: The curtain shouldn't be made of heavy material, such as canvas, due to the weight. Half of mine is made from a thin painter's dropcloth, folded double and dyed black. The other half is salvaged doubleknit material, folded double, which I got free. The poles should be metal, not wood, as there is considerable lateral stress from the weight of the curtain and tension of the cable. For the same reason, the holes and ABS pipe should be at least two feet deep in fairly firm ground. The bottom of the ABS pipe could also be capped to prevent ground water seeping in.

The shelter is not a beautiful thing to see, but it is extremely functional and has saved me much aggravation. I hope a few readers will build one and take their telescopes out of the attic.

Chuck A. Ainge
2807 Fordham Lane
Raleigh, NC 27604



Wojciech Konefal Observatory

The Wojciech Konefal Observatory was built by myself and my friend Robert Konefal. It is situated at the end of his private runway, the Capt. Herbert Vickers Airfield. The property is located in Newfield, New Jersey, longitude 75° 6′ west, latitude 39° 34′, about 30 miles southeast of Philadelphia. The closest town, Vineland, is 7 miles to the south, and does give us some sky glow. Other than that, skies are reasonably dark, allowing us to see down to 6th magnitude on good nights.

We began construction on May 21, 1977, working on Saturdays and holidays. Completion took 6 months involving 250 man-hours and $1700 in material. We decided on a roll-off roof type building, because it affords an entire view of the sky to observe meteors and other celestial phenomena.

The building is built on a concrete foundation 20′ x 14′, including a separate combination storage and winter warm-up room. The walls are 2 x 4s covered by exterior plywood and painted. The observing area has a 26″ high raised platform with two permanent piers (pipes filled with concrete extending 36″ into concrete filled holes). The 3″ pipe holds a Celestron 8 and the 5″ pipe holds a 12½″ f/5 Newtonian telescope.

Electricity is provided by underground wiring approximately 130 feet from the house. Interior lighting is controlled by a variable dimmer switch.

Over the observing area, our roll-off roof has a 16′ x 14′ clear span. The roof is framed out in 4 x 4s and 2 x 4s covered with aluminum sheets and has a pitch from back to front of 12″. Track assembly and rollers were obtained from a local overhead door company. The roof weighs approximately 500 pounds and can easily be rolled off with one hand. It has withstood 6″ of wet snow successfully without supports.

Our observatory has given us many pleasurable leisure hours that we've enjoyed sharing with friends, family, and school children, who are developing, like us, a deep interest in the heavens.

Paul D. Kandle
409 Wesley Avenue
Pitman, NJ 08071

Equatorial Mount for a 10″ Reflector

Recently I built an equatorial mount for my 10-inch reflector. It's an inexpensive design that TM readers may find helpful.

The mount is constructed from two 2″ pipe "tees," scrap 1″ steel shafts you can find at most machine shops, and inexpensive trailer bearings. The 25-pound counterweight is a scrap car wheel bought for $3 from a scrap yard which, at the time, charged me 12 cents a pound for steel.

2″-pipe tees are large and sturdy enough for a 10-inch reflector and hold 1″ trailer bearings. You can buy these, for a small amount, from marine shops. 1″-steel collars with set screws hold the bearings in place (purchase from a mill supply company). I had a hole tapped in both tees to hold locking screws made from common outside water faucet handles attached to bolts. Nuts hold the handles on securely.

I picked up two 1″ shafts at a machine shop for nothing, and had them welded at the indicated points on the drawing.

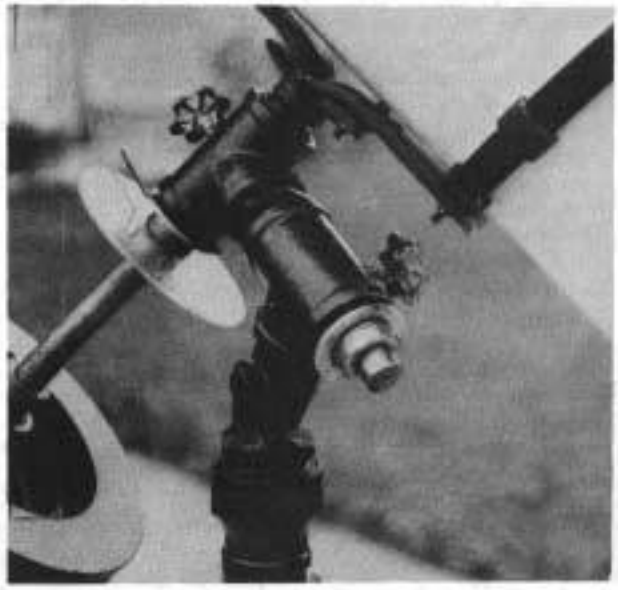
I used a telescope cradle made of two steel bars 12″ long, bolted to the top flange and purchased a bar of aluminum ¼″ thick and 1″ wide to mold the cradle. Aluminum strips can be purchased at a hardware store and, although workable, are rigid enough to do the job. A wooden cradle could be used instead, depending on your shop skills.

Probably the greatest expense involved was in welding the steel plates for the latitude adjustment. Maybe you can find a welder to do it for you free. The plates were scrap, available at machine shops, and should be at least ½″ thick.

To start construction, grind down the threads on four surfaces of the pipe tees very slightly so the bearing races fit the tee. They almost seem as if made for the job. Grind away the threads only as far down as the thickness of the races. The remaining threads serve as stops to hold the races in place. The grinding can be done with a small grinding stone for a ¼″ drill, or on a drill press using constant circular motion to grind the threads off evenly. Washers and locking collars hold the bearings in the pipe tees for a snug fit.

The pedestal and base are built by welding 1½″ pipe sections to a 2″ center section with crossbars of steel welded for support. Castors obtained from a hardware store attached with "U" bolts make the scope portable.

Paul Doyal
716 Avenida De Golf
Milton, FL 32570



The weekend of June 1-3, 1979, brought some ninety persons to the campus of Missouri Western State College, St. Joseph, Missouri, for the 29th annual convention of the Mid-States Region of the Astronomical League. The Midland Empire Astronomy Club and the Astronomical Society of Kansas City were co-hosts for the convention.

Mid-States Regional

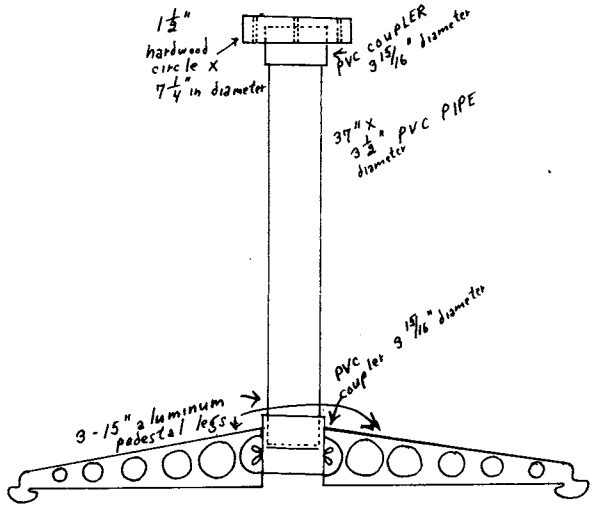
Star parties were held both Friday and Saturday nights at the Observatory of the Midland Empire Astronomy Club, some 8 miles northeast of the city of St. Joseph. Skies were sparsely cloudy Friday, while on Saturday conditions were almost perfect and following the first quarter moonset about midnight, some really serious observing took place among the many who made a night of it. Telescopes ranged from modest 3" aperture to the 20-inch f/6 Newtonian of the MEAC club. This instrument was performing superbly and under the guidance of Milton Rose (of the Astronomical Society of Kansas City) who designed it, many saw deep-sky objects as never before! Bob Cox, Associate Editor of TELESCOPE MAKING magazine, brought along a prototype model of the Jones-Bird all-spherical reflector which was a real revelation of the superb images and resolving qualities in a 6" f/6 system! Mr. Cox's 6" Buchroeder Yolo gave viewers some really excellent views of Jupiter and Saturn.

The variety and range of the convention papers sessions showed the progress astronomy has made in the past three decades since this region of the League was formed. Some of the topics and authors follow:

"Improving Telescope Performance" by Bob Cox, "Photoelectric Photometry" by Dr. Charles Don Gielker, "Why the Sky is Dark at Night-New Thoughts on Olber's Paradox" by Clarence Annett, "400 Year History of Ringed Planets" by Clay Sherrod, and "Astrophotography with Afocal Techniques" by Walker Manly, Jr.

Following the Saturday night buffet supper, William "Bill" Schoenig, a staff member at Kitt Peak National Observatory, gave a slide/lecture tour of the variety of instrumentation at Kitt Peak, as well as Cerro Tololo and the European Southern Observatories in South America, with some first generation slides of deep-sky objects seen with some of the large aperture instruments high in the Andes Mountains. Bill Schoenig was born in St. Louis, MO and graduated from Central Methodist College (Fayette, MO) where as an undergraduate student he was a member of the Central Missouri Amateur Astronomers. He is now in charge of the photographic laboratories at Kitt Peak. All felt honored to have him speak at this convention and regard him as "one of the boys" who has made good in the field of professional astronomy!

Russ Maag
1979 Regional Co-Chairman
and V.P. MEAC Reporter



A Mount for a Small Cassegrain

I had just purchased a small Cassegrain telescope and, since my budget was limited, I was wondering how to mount it along with its equatorial wedge. I knew that I could purchase an excellent one from the supplier, but they ran from $95 to over $200. I was determined to build one myself!

From a telescope supply house I bought three 15" aluminum pedestal legs. A local hardware store supplied a 3½" (o.d.) piece of polyvinyl chloride pipe (PVC) 37" long and two PVC couplers, one for each end. With epoxy I glued one coupler onto the end of the 37" pipe. Three holes 120° apart were drilled into the bottom half of this coupler to accommodate the aluminum legs. Since the pipe must rest on the center rim inside the coupler, the pipe must be level on both ends. I attached the aluminum legs with the screws and wing nuts provided. The base was completed.

From a piece of hardwood stock 1½" thick, I cut a circle 7¼" in diameter. A local custom woodworking shop reamed out a circular channel 3-15/16" across and ¾" deep. I glued the second coupler into this countersunk channel, which I also made sure was level. Before mounting this unit onto the top of the pedestal, I had three holes drilled in the circle so that I could attach the wedge to it. Then I glued the completed piece onto the PVC pipe.

After mounting the sleeves or collars to the main tube assembly with epoxy glue or some other strong adhesive, I drilled three ¼" holes 120° apart and inserted ¼-20 x 1" stove bolt with lock washer and nut. This gives added strength and support to the tube assembly.

I primed the whole with grey primer and used a flat black enamel for a finishing coat. My mount is sturdy, fairly light, and the legs come off for easy carrying to distant sites. I use it both as an observatory platform and for astrophotography. Total cost — $35.27.

Robert W. Huber
904 11th Ave. W.
Ashland, WI 54806

To Giraffe or Not to Giraffe

Both amateurs and the industry making telescopes for them know how to make fairly good telescopes. There are, however, two flaws in their design. First, there is excessive vibration, and second, they're all neckbreakers.

Not having any giraffes among my ancestors, I designed a mount that is stable, cheap, and easy on your neck. It is an alt-azimuth design, but an equatorial using the same principle could also be constructed.

Azimuth rotation is obtained by mounting your reflector or refractor on a front wheel of a car mounted horizontally on a concrete pier. The wheel I am using has two roller bearings and is very smooth.

Altitude control is obtained by a flat first surface mirror mounted in front of an always horizontal reflector or refractor. The mirror is rotated by a good quality, spring-loaded worm gear. Until recently such a mirror was hard to find, but since the appearance of photocopy machines, there are plenty of them on the surplus market. Edmund Scientific is another source. Mirrors must be elongated — 6" x 10" is minimum size for a 6" telescope — and the price is about $10.

The flat mirrors need not have their quality expressed in fractional wavelengths as long as they don't introduce any distortion. I checked mine with my 6" RFT.

The camera, which you see in the picture, has a snap-on back plate with the eyepiece in it. If this plate is replaced with a film magazine (2¼" x 3¼"), the film would be in the primary focus.

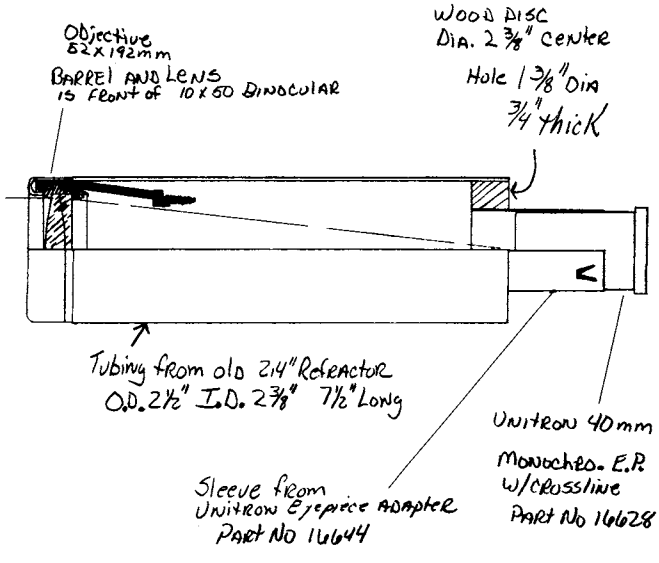
When I go to a star party, I mount my 6" refractor on a lazy susan bolted to the roof of my car. This particular lazy susan can carry a 600 pound load and was obtained from Edmund Scientific.

Apart from being nearly vibration-free, this arrangement will keep your eyepiece always at your eye level, no matter what star you are looking at. No need to giraffe!

V. Gercke
Box 143
Weimer, CA 95736

A Homemade Finder

Three months ago I finished a 6" f/5 reflector, and was in need of a finder larger than my old 30 mm one. (Up here in Anchorage, half the clear nights are afflicted with aurora activity and that makes a 30 mm finder almost useless on all but the brightest stars.) So I checked the prices on larger finders and figured I could make one for less. With a wife and three kids, it's hard to come up with money for hobby purposes.



What you see is the result. I've used it and found it to be more than I expected. With an 8° field and 50 mm objective, those hard-to-find objects don't escape anymore. I'm pleased: anyone with an old pair of 50 mm binoculars lying around can make the same finder I have. Around here if the temperature drops below 10°, I don't have to take my 6" out but I do go out with the finder for RFT observing. And it works great.

I have sent the original drawings (which are reproduced here) and hope that you can use this article.

Keith Lawson
1135 W. Oldfield
Lancaster, CA 93534

The PEP Gang

By R. Genet, D. Hall, G. Henry, L. Kalish, H. Landis, H. Louth, L. Lovell, J. Mattei, T. McFaul, R. Minton, T. Renner, A. Stokes, and R. Walsh.

Introduction

All the faithful readers of TELESCOPE MAKING should, by now, have a telescope or two made, or at least well under way. The more fortunate of them will be prefectly content to casually gaze on pleasant evenings at the many astronomical wonders on display. There are, however, bound to be a few malcontents who will take the perfectly unreasonable goal of gathering scientifically usable data under conditions and times not always pleasant, with precise, but sometimes finnicky and exotic instrumentation. Only these unfortunate souls should read on.

There are three basic requirements that usually must be met if amateurs are to contribute to the advancement of astronomical knowledge. These are: (1) amateur observatories equipped with instruments of the necessary precision, operated in a careful and regular manner; (2) professional astronomers willing to guide and monitor the amateurs to make certain that needed data is gathered under the proper conditions; and (3) some organization, informal or otherwise, that connects the amateurs with the professionals.

It is the objective of this article to describe a group of professionally sponsored amateurs which, to a considerable degree, meets these requirements. As is appropriate for TELESCOPE MAKING, the emphasis has been placed on pictures and descriptions of the telescopes and equipment the amateurs have built or assembled themselves. The story would be incomplete, however, without the professional side.

Photoelectric photometry (PEP), as its name implies, is the measurement of light via the photoelectric effect. In astronomical PEP, the light intensity and color of astronomical objects are measured versus time. These measurements are generally relative comparisons between two stars or other objects.

The group engaged in this precise and demanding work is small, so it is only natural that the "PEP Gang" engages in considerable lighthearted banter. It appears to be an integral part of amateur PEP, so it's been included as an antidote to the serious aspects.

We've neglected, almost certainly, to include all the amateur astronomers equipped for PEP, and we've equally surely missed some professionals who use amateur data. We apologize to those not included.

We begin, now, with the professional side of the story:

Dr. Hall's War

Dr. Douglas S. Hall and Gregory W. Henry at Dyer Observatory have an active research program that has extensively utilized data from the amateurs mentioned later in this paper. "Papa Doug," as Dr. Hall is called by the amateurs, makes occasional visits to his "gang," thus keeping them on the straight and narrow path in the proper collection of usable scientific data.

To emphasize his conviction that amateurs can do "real astronomy," Dr. Hall shares authorship with those who supply usable data. Co-authored papers have appeared in reputable scientific publications: the *Astronomical Journal*, the *Publications of the Astronomical Society of the Pacific*, *Acta Astronomica*, the *International Astronomical Union Commission 27 Information Bulletin on Variable Stars*, the *Journal of the American Association of Variable Star Observers*, and last, but certainly not least, TELESCOPE MAKING with the publication of this paper.

The principal theater of battle in Dr. Hall's war with the unknown involves the still puzzling RS Canum Venaticorum (RS CVn) binaries, which have been discussed recently in ref. 6. Many other professional astronomers have been drawn into the battle lately because of the unexpected discovery of very strong emission radio waves from these stars (100,000,000 times that of the Sun), the discovery of unusually strong chromospheric activity by satellite observatories like COPERNICUS (OAO-2) and the International Ultraviolet Explorer (IUE) observing in the far ultraviolet, and the even more recent startling discovery of a very strong emission of X-rays (100,000 times that from the Sun) by the newly orbited High Energy Astrophysical Observatories (HEAO 1 and HEAO 2).

Still not understood is the "mysterious wave" which superimposes on what should be a normal eclipsing binary light curve, a strange photometric distortion outside eclipse. An interpretation proposed by Dr. Hall back in 1972, unpopular at the time, seems to be the one most favored now: one hemisphere of one of the two stars is covered roughly 20% by large dark starspots, presumably analogous to sunspots (even though the Sun's surface is never covered more than 0.1% even at sunspot maximum). Major questions still not at all understood include: (1) Why are the spots so huge, or if they are small, why are there so many? (2) Why do they prefer to stay bunched together on only one hemisphere for years or decades on end? (3) Why does the spot group always rotate at a rate very nearly equal to but never exactly equal to the orbital period? and (4) Will this starspot activity ebb and flow on a given star as sunspots do in the Sun's 11-year spot cycle?

For many reasons, amateur PEP observers are ideally suited for getting the photometric data needed to answer these tough questions. First, the mysterious wave almost always has an amplitude around 0.1 or 0.2 magnitude, relatively easy for PEP, but out of reach for visual or photographic estimates

(useful for variability in excess of 0.3 mag.).

Second, around half of the known RS CVn variables are of naked-eye brightness or nearly so. Thus telescopes as small as 6" in aperture can be used in the battle.

Third, the slow drift of the mysterious wave and the search for the suspected spot cycles, which both occur on time scales of years, require the perseverance and force of numbers which amateur PEP observers can provide better than can harried, overworked, and sometimes impatient professionals.

At Vanderbilt, Dr. Hall and Gregory Henry analyze the photometric data supplied by the amateurs. Using a Univac 1001 Card Processor and the newer DEC-10 Remote Terminal, they enter data into the XDS Sigma Seven and into the newer DEC-10 for analysis. Intermediate output is displayed on the screen of a remote terminal for monitoring and editing, and hard copy appears on the line printer and simultaneously on a CALCOMP plotter.

Basically what they do is: start with data in the form of time and raw differential magnitude; apply the appropriate heliocentric correction for each night; compute orbital phases for each point using a known ephemeris; compute accurately the differential atmospheric extinction correction; and transform magnitudes to the standard UBV system. This last step is essential for combining data from the many very different amateur observatories into one complete light curve.

Fig. 1 Dr. Hall in action at the Dyer Observatory (Photo by Jane Word).

To do this, they need auxiliary information including: accurate positions for each variable and its comparison star; atmospheric extinction corrections appropriate for each season and each geographical location; each amateur observatory's terrestrial latitude and longitude; and the transformation coefficients for each amateur's photometric system.

In the space of a few years, amateurs under the guidance of Dr. Hall have made PEP observations resulting in the discovery of 6 new variable stars, most of them naked eye: V711 Tauri = HR1099, 2 Corona Borealis, Geminorum, HR4665, HR5110, and HD86590. (In fact, even more have been discovered by now, but Dr. Hall doesn't want to leak results prematurely.) Using certain tricks and subtle astronomical clues, Dr. Hall can predict which stars, previously thought to be constant, are actually variable. To date his batting average, in terms of stars looked at versus variables discovered, is running around 50%.

As can be seen from fig. 1, Dr. Hall is by no means just an armchair theoretician, but is also an experienced and active observer. The slightly surprised look on his face is due to the fact that he just discovered it's the filar micrometer attached to the 24-inch Seyfert Baker Reflector/Corrector at Dyer instead of the photometer. No wonder he couldn't get any star deflections! It took him only

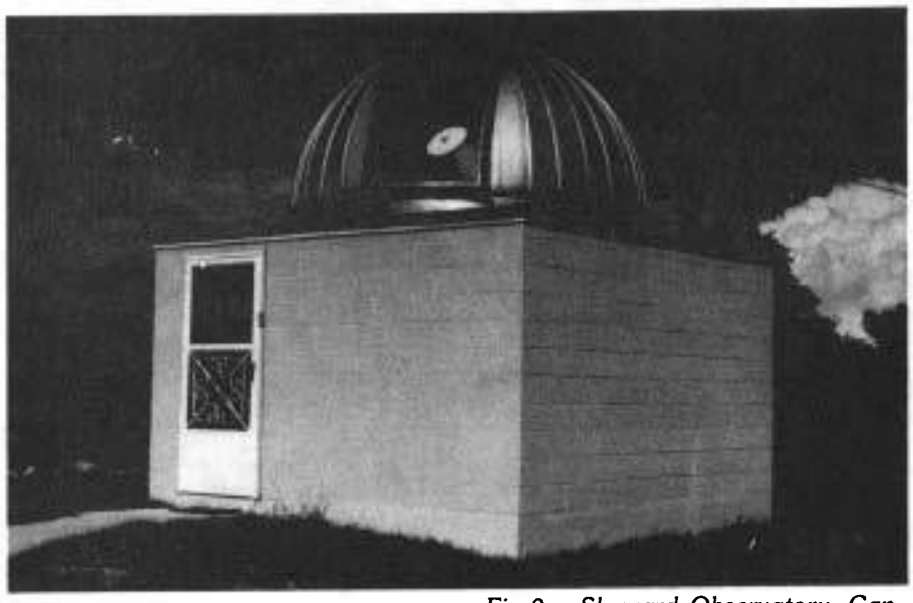


Fig. 2 Skyward Observatory, Canyon Hills, Texas.

5 minutes to figure this out (not bad for a Ph.D.).

"Papa Doug" and Greg are both AAVSO members, and can be contacted at the Dept. of Physics and Astronomy, Vanderbilt University, Nashville, TN 37235.

So much for two of the pros, now let's get on to 12 of the hams:

The PEP Gang of Twelve

Being basically a square shooting group, but without consulting Renner, Skillman, Stokes, or Walsh, we decided that the only fair thing to do was to go in alphabetical order. Thus, we start with Col. Fisher.

Col. Gordon F. Fisher

Gordon has realized a lifelong dream to have his own observatory. His extensively reworked Star Liner 12.5-inch covertible Cassegrain/Newtonian telescope is housed in the domed structure shown in fig. 2. It overlooks a lake 40 miles north of San Antonio, Texas. Gordon's photometer is a Pacific Instruments Model 110, seen in fig. 3. It employs an RCA 1P21 photomultiplier tube (PMT) and thermoelectric cooler. The cooler's heat exchanger is supplied by water from a 35 gallon tank. Fortunately, it doesn't freeze too often in southern Texas.

Supporting instrumentation includes a Heathkit strip chart recorder, shortwave receiver, and UT and local sidereal clocks. Gordon is a retired Air Force surgeon and is assisted in his observations of RS CVn variables by his charming wife, Winnie, at the Skyward Cottage and Observatory. Gordon is a member of the AAVSO. His address is 2319 W. Gramercy Pl., San Antonio, TX 78201. It is not true, as rumored, that

➤

Gordon repairs his photometer with surgical instruments while wearing a face mask and gloves.

Russell M. Genet

Russ is a relative newcomer to the "PEP Gang" (but a real go-getter! -TM ed.). Fig. 4 shows his 8-inch Cassegrain telescope being readied for a night's work at the Fairborn Observatory. Russ's photometer head is an original design (no one else would claim it) constructed from model aircraft plywood and epoxy. He uses an uncooled RCA 1P21 PMT, and his DC amplifier and PMT power supply are based on a design by Art Stokes (suitably modified to fit scrounged parts).

Russ is interfacing his TRS-80 microcomputer to his photometer and WWV (time reference) receiver. An electrical engineer, Russ works as an operations research analyst for the Air Force. Because of his long letters and articles, Russ is suspected of having a certain unmentionable disease of the pen. For details on his observatory, see ref. 1. Fig. 5 shows Russ (Jr.) and the "plywood wonder" photometer in operation. Russ (Sr.) is also a member of the AAVSO. His observation program, just begun, includes RS CVn variables, suspected Yale B.S. variables, Mira, and lunar occultations. He can be easily reached for lengthy replies at 1247 Folk Rd., Fairborn, OH 45324.

Len Kalish

Len lives in Los Angeles, California. Due to a slight light pollution problem, he commutes to an 8-inch Cassegrain telescope located 90 miles north of Los Angeles. Len is a member of the Polaris Observatory Association, a group of Los Angeles amateurs who banded together and built their own observatory in the mountains. Len's photometer uses an uncooled RCA 1P21 PMT, and he can be seen in fig. 6 standing behind the photometer and the group's telescope. As can be seen, Len is rapidly catching up with Dr. Hall in the "chin fuzz" department.

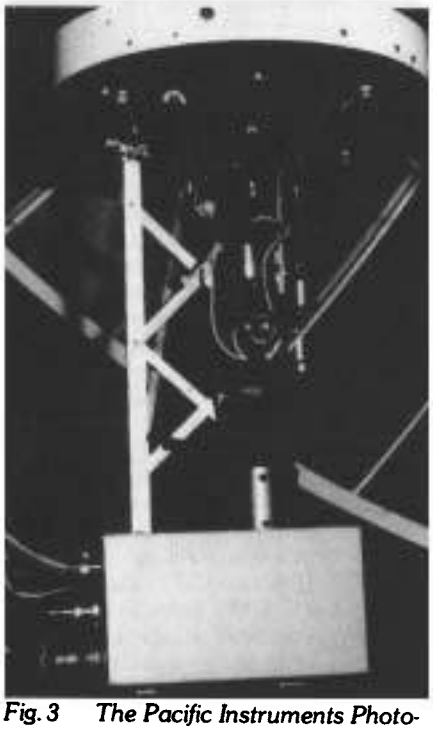


Fig. 3 The Pacific Instruments Photometer mounted on Col. Fisher's 12.5-inch telescope.

Fig. 5 Russ (Jr.) at the controls of the "Plywood Wonder" demonstrating how easy PEP really is

(Photo by Dan Hollingsworth).

Fig. 4 Russ (Sr.) rolls off the roof at the Fairborn Observatory.

The DC amplifier/power supply, clock, and Heathkit strip chart recorder can be seen in the foreground. His primary interest is in eclipsing binaries with varying periods, and he likes to track the changes from year to year. Len has a SOL-20 microcomputer that he uses to reduce and analyze his data. Len recently retired from Thomson Ramo Woldrich (TRW). He has been gathering PEP data for a number of years, and has been a co-author of several papers. Len, another AAVSO member, can be reached on cloudy days at Apt. 3, 580 S. San Vicente Blvd., Los Angeles, CA 90048.

Howard J. Landis

Howard recently moved his domed observatory to the peaceful Georgia pasture shown in fig. 7. Those with X-ray vision can see Howard busily trying to finish the shutter on the other side of the dome. This picture proves once and for all that the Landis Observatory is not in the middle of a Georgia cotton field (as some of us have stubbornly maintained).

His telescope is an 8-inch Newtonian, and his home-built photometer uses an uncooled RCA 1P21 PMT. Howard and his photometer are seen in action in fig. 8. Howard is chairman of the AAVSO PEP Committee and is an active observer of variable stars, including eclipsing binaries. He uses a Digital Group microcomputer to analyze his data and even write letters. Howard is one of the PEP old-timers, and has co-authored many papers published in the professional journals. The Landis Observatory can be reached by writing to RFD Box 44ED, Locust Grove, GA 30248.

Howard Louth

Howard designed and built his unique 11-inch Cassegrain/Maksutov telescope which is housed in a revolving structure. The telescope and observatory are shown in fig. 9. The photometer and supporting electronics are mostly home designed and built. This includes a pulse counter (instead of a DC amplifier), a digital Julian day clock, and an automatic printer. He "tunes-up" these pulses with a wide band oscilloscope. Howard is an active observer of variable stars, especially eclipsing binaries. Howard is another of the old-timers with years of

Fig. 6 Len Kalish and his photometer at the Polaris Observatory in the Californian mountains.

Fig. 7 The Landis Observatory and staff quarters in their pasturesque (sic) setting.

observation and several publications bearing his name. Details on his unique telescope and observatory can be found in ref. 2.

Fig. 10 shows a close-up of Howard's latest photometer head, and as can be seen, it is a work of art. Howard is another AAVSO member and can be reached at 2199 Hathaway Road, Sedro Wooley, WA 98284. Howard says "that without photometry I would have virtually no use for a telescope, as in eight years I have not had conditions suitable for lunar or planetary photography." This could, of course, just be the well-known Washingtonian bad-weather ploy to keep from being overrun like California.

Larry P. Lovell

Larry's 10-inch Cassegrain telescope is located in a large domed observatory near Chagrin Falls, Ohio, the exact location of which is a well-kept secret. His photometer and supporting electronics were designed and built by Art Stokes, along with a no-cost lifetime maintenance guarantee, which is fortunate since Larry doesn't know a vacuum tube from a transistor. In 13 years of very active observing, Larry has observed almost every type of variable star.

Fig. 8 Howard gathering some RS CVn data for Dr. Hall.

Fig. 9 The 11-inch telescope and supporting electronics in the revolving Louth Observatory.

Larry is an interior decorator and, as you can tell from his lack of a photograph, prefers to remain anonymous. The rest of us aren't even sure of his real name. He also has many publications to his credit. Larry, a longtime active member of the AAVSO, is rumored to be reachable at 18410 Munroe, Chagrin Falls, OH 44022, although this could easily be a false lead.

Thomas G. McFaul

Tom's 8-inch and 14-inch Schmidt/Cassegrain telescopes are housed in the very attractive roll-off roof observatory shown in fig. 11. Tom uses an Op-Tec solid state photometer with a silicon diode detector as the active element. It can be seen attached to the 14-inch telescope on the left of fig. 12. He is active in RS CVn variables, eclipsing binaries, and RR Lyrae variables. He uses a filar micrometer, which he has extensively modified, in conjunction with his photometer to measure the simultaneous position and light fluctuation of asteroids. If Tom gets a third telescope, we're all going to be jealous.

Tom has done some very interesting comparisons between the results he gets with his Op-Tec photometer and the standard values published in the Arizona-Tonantzintla catalog. Tom, another AAVSO member, can be reached at East Hook Cross Road, Hopewell Junction, NY 12533.

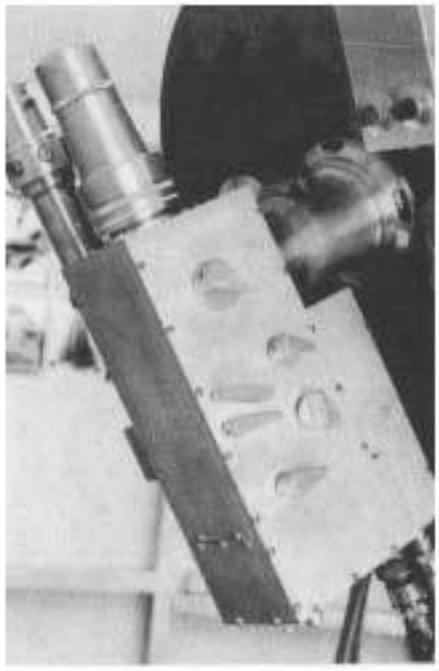


Fig. 10 Louth's homemade photometer, a true machinest's delight.

R.B. Minton

R.B.'s 6-inch Newtonian is housed in his observatory near Tucson, Arizona. He designed and built his photometer, which utilizes a cooled RCA 1P21 tube in a cleverly designed and insulated box. R.B. also designed his own electronics which consist of a DC amplifier, a very husky and stable power supply (in fact, it's rumored he poured a second concrete pier just to hold up the power supply), and a voltage-to-frequency converter and counter. He can also use his photometer in conjunction with a KIM-1 microcomputer for automatic guiding in right ascension. This clever scheme is described in ref. 3.

R.B. is no stranger to using computers as he works as a programmer for the Remote Sensing Laboratory of the University of Arizona. Some of his most interesting PEP observations have been of comets. R.B., an AAVSO member, resides at 8617 E. Stern Lake, Tucson, AZ 85730.

Thomas Renner

Tom does his PEP observations from Scuppernong Observatory which he recently equipped with a 14-foot dome (ref. 6). Under the dome is a 10-inch f/5.7 Newtonian telescope. The telescope and equipment can be seen in fig. 13. Tom built his own photometer head which

➤

Fig. 11 The very attractive McFaul Observatory.

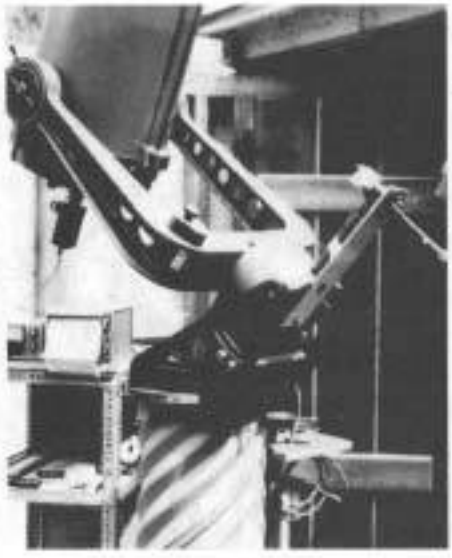


Fig. 12

Fig. 13 The business end of Scuppernong Observatory.

contains the standard UBV filters and a 1P21 PMT. The DC amplifier and solid state regulated power supply were built by a local friend, Bob James. Results are recorded on a 5-inch strip chart recorder and also displayed on a 5-inch meter.

Tom has been an amateur astronomer for 10 years and a member of the PEP Gang for the last 3 years. Tom's first PEP observations were a total disaster as he unknowingly had a bad PMT. Tom is a civil engineer specializing in water works, another AAVSOer, and can be reached at 4512 Deerpark Dr., Dousman, WI 53118.

David R. Skillman

Dave's 12.5-inch Cassegrain telescope is located in an observatory cleverly disguised as an attractive tool shed (when folded). Dave designed and built his photometer and electronics. It uses an uncooled RCA 1P21 PMT. His telescope is moved by stepper motors controlled by a KIM-1 microprocessor. Dave observes several types of variable stars and also uses his photometer and computer for precision timing of occultations.

Dave works on satellite computer software at the NASA Goddard Space Flight Center in Greenbelt, Maryland. It's rumored that he will soon have his telescope and photometer so automated that it will gather data while he sleeps. An AAVSO member, Dave had observed for several years and has several publications to his credit. He can be reached at 9514 48th Ave., College Park, MD 20740.

Arthur N. Stokes

Art's 16-inch Newtonian telescope is located in a domed structure in Hudson, Ohio. Art started in photometry in 1963 and was chairman of the AAVSO PEP Committee for several years prior to Howard Landis. Although he had done a good deal of observing, his forte is designing and building equipment. His photometer head is among the most cleverly designed, and his DC amplifier and power supply design have been used by others. Art has built several photometers and is presently building one for the DeWitt 12-inch reflector at the Dyer Observatory of Vanderbilt University.

Art is a chemist by profession, but an electronics buff at heart, and works at Reuter and Stokes in Cleveland, Ohio. When asked why his power supply had vacuum tubes in it, Art said he likes the cheerful glow and warmth they provided (understandable in Ohio). You can communicate with Art, a long standing AAVSO supporter and member, by writing to him at Box 398, Hudson, OH 44236.

Robert Walsh

Bob's 12.5-inch Newtonian telescope is located in beautiful Sedona, Arizona, near the picturesque Oak Creek Canyon. His nicely landscaped roll-off roof observatory is shown in fig. 14. Bob is shown in front of his telescope in fig. 15. The photometer uses an uncooled 1P21 PMT, and is powered by a GCA/McPherson regulated supply. Bob's DC amplifier was built by Art Stokes and has been trouble free, which is a good thing as Bob couldn't talk Art into a free lifetime maintenance guarantee due to his distance from Art. Results are recorded on a Heathkit strip

Fig. 14 The nicely landscaped Walsh Observatory.

chart recorder. Bob's observing program includes eclipsing binaries such as U Cephei, and, of course, Dr. Hall's RS CVn variables.

Bob is an engineer who spent many years in the design of power plants. He retired early so he could fulfill a lifelong dream to have his own observatory in Arizona. Bob is another AAVSOer.

...And the AAVSO, Of Course!

All the amateurs mentioned in this article are members of the American Association of Variable Star Observers (AAVSO). This scientific organization, founded in 1911, is the largest organization of variable star observers in the world with about 1100 members worldwide. Its purpose is to make the observations of amateur astronomers useful and available to professional astronomers. Its headquarters at 187 Concord Avenue, Cambridge, MA 02138, receive about 150,000 observations a year from about 400 active observers. Since 1911, over 4 million observations of variable stars have been compiled by the AAVSO.

AAVSO is directed by Janet Akyuz Mattei. Janet is AAVSO's third director, succeeding Leon Campbell and Margaret Mayall. She is a native of Turkey and was educated in astronomy both in Turkey and the U.S.A. She is particularly interested and encourages the interaction of AAVSO with professional astronomers. In the past year, about 100 astronomers requested data from the AAVSO.

The AAVSO's interest in PEP goes back thirty years. Many members vividly remember John Ruiz, "AAVSO's Cartoonist Laureate," as he was called, who ignited the interest of the AAVSO in PEP observations. His papers, given at AAVSO meetings, illustrated with squirt guns and gremlins to explain how PEP systems work, were both informative and entertaining. In fact, Art Stokes, John Ruiz, Leonard Kalish, and Donald Engelkemeir wrote the AAVSO's "Manual for Astronomical Photoelectric Photometry."

Amateurs received valuable help in getting started on PEP by contacting the chairman of the AAVSO PEP Committee. For a number of years the chairman was Art Stokes, whose help often went so far as building and installing amplifiers and photometer heads of his own design. The present chairman, since 1974, is Howard Landis, who has worked hard to help aspiring PEP observers during the painful initial stages of getting their equipment actually functioning properly.

Conclusions

If you're one of the unfortunate sort of persons who enjoys maintaining acrobatic positions hours on end while flipping the same levers and turning the same knobs over and over again...

If you thrive on being eaten alive by mosquitoes in the summer and freezing in the winter...

...then photoelectric photometry (PEP) may be for you!

Seriously, though, PEP provides a way for the amateur to make important contributions to the advancement of astronomical knowledge. It can be very exciting and rewarding, although it does take considerable patience, perseverance, and precision. While it is not particularly easy or cheap to equip yourself for PEP, the readers of TELESCOPE MAKING routinely do the impossible! The amateurs and professionals mentioned in this article are generally more than glad to answer questions and help anyone get started. A good first step, if you're interested, is to obtain references 4 and 5 cited below and read them. Also, write or visit one of the members of the PEP Gang.

The amateur PEP observer has one great advantage over the professional: he doesn't have to schedule very limited observing time in advance on a crowded schedule. This is a considerable advantage when one considers that photoelectric photometry is an activity in which only one star can be observed at a time. The old saying "there are so many stars and so few astronomers" applies here as much as it ever has. Why don't *you* be the lucky one to make it the PEP Gang of Thirteen?

We wish to acknowledge the TM editor, Richard Berry, for his patient support of this article, and Judy Grinter for typing the several drafts. All photographs by the authors, except as noted.

Fig. 15 The interior of Bob's well-equipped observatory.

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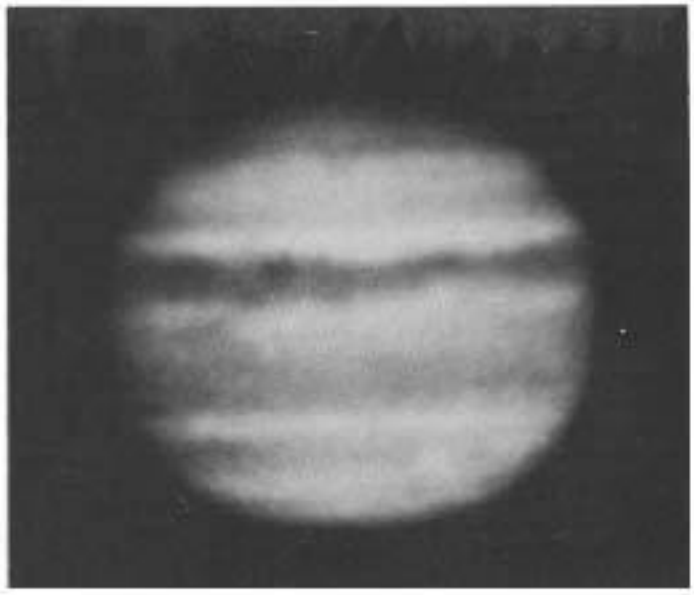
the Questar 12



I visited the Questar Corporation in New Hope, Pennsylvania for the first time in June, 1975. There I met Mr. Robert Richardson, a very well-known astro- and planetary photographer, and Mr. John Schneck, both executive officers of the corporation. At that time, I owned both the 3½ and 7-inch Questar telescopes which had performed exceedingly well for me for a long period of time.

But now I was in the market for a larger instrument with equally accurate optics, and this led to my visit of Questar's plant. We discussed the possibility of designing and building a larger Questar than the 7, and, as it turned out, they'd had a 12-inch instrument under consideration for some time, but it had not yet reached the drawing board stage. As a result of our discussions, I placed an order for a custom-built 12-inch reflector telescope with the Questar Corporation. In other words, the first Questar 12 was "conceived" in June 1975.

The optical barrel assembly is designed to hold a Maksutov/Cassegrain Catadioptric optical system having a clear aperture of 12-inches. The focal length is 180", i.e., f/15, with a field of view of 0.48°. The primary mirror, 12.67" in diameter and f/2.1, is Pyrex with an Al/SiO coating, and receives light through the BK-7 glass corrector lens, 12.35" diameter. The secondary mirror is coated on the corrector as a spot 2.84" in diameter. The back focal distance is 19.24". All of this requires a barrel with an overall length of 41.5", weighing approximately 125 lbs.

We chose a German Equatorial mounting as most suitable to carry this barrel assembly, principally because extremely fine and accurate mountings of this type were already in manufacture at the Byers Company of Barstow, California. Also we felt that the weight of the optics and their resolving power requires an exceptionally precise operating mounting. The Byers mounting, custom-built for this instrument, met the specs. We required the polar axis to be 3½-inches in diameter at the upper bearing, declination axis 2½-inches minimum; polar axis adjustment by hand is included from +5° to +70°.

The right ascension drive gear is a 359 tooth, 11-5/16-inches diameter worm wheel with precision stainless worm, Bodine A.C. Precision motor providing sidereal tracking with an accuracy of 5 arc-seconds maximum periodic error. The weight of the mounting is 175 lbs.

A four button operational hand control controls both the declination drive-direct reversible motor and the right ascension drive. Two push buttons allow positioning on the declination axis while the two other push button controls increase or decrease the right ascension drive motor speed for tracking. The push button control panel includes a vernier dial controllng a variable frequency power supply to enable accurate adjustment of the right ascension drive motor speed.

This instrument is the one shown in Questar's ads for this line of telescopes. Its features are shown beautifully, the beautiful golden color finish, and the inscription:

Byers-Questar
12 inch telescope
Barstow, California
New Hope, Pennsylvania

The optics were tested by Richardson and Schneck at Questar. On one exceptionally cold clear night, with seeing at its best, they pronounced them to be rather extraordinary. The final wave front was better than 1/10 wave length accurately flat peak to valley. A resolving power of 0.38 arc-seconds was obtained. Richardson photographed Jupiter with this barrel assembly, obtaining the picture shown here.

The telescope was completed in January 20, 1977, as indicated by the inscription at the base of the barrel, and has the serial number 001. It arrived in Palm Beach three weeks later. I obtained an Observa-Dome to house the telescope, and set it up on March 5, 1977.

I've mounted the 3½" Questar on the left of the finder scope to serve as a guide scope and a Questar 700 lens mounted on the right side of the finder for wide-angle astrophotography.

Saturn, recently very much in the news with the Pioneer 11 approach, has been perhaps the most exciting subject of my observations and photographs. On the night of December 22, 1977, an exceptionally clear and stable seeing period allowed me to observe the rings of the planet well placed, the Cassini separation in the ring system clearly visible.

The Byers-Questar 12 is indeed a quality instrument, perhaps the best quality instrument available of its size to date. Comfortably nestled in its dome, this telescope has successfully survived Hurricane David and, I am sure, will be the source of many exciting observations and astrophotographs with clearing skies.

Ernest B. Wright
249 Royal Palm Way
Palm Beach, FL 33480

Some of Mr. Wright's stunning photographs will undoubtedly appear in ASTRONOMY during the coming months. — Ed. ■

build this

simple astro mount

Astrophotography without a telescope — or guidescope? With a Haig mount, wide-field and short telephoto sky photos are within the reach of anyone — even the rankest beginner — who owns a camera with a time setting.

The original simple astro camera mount was described in the April 1975 issue of *Sky & Telescope* by Professor George Haig. Since then dozens of variations on the basic idea have been published in astronomical magazines the world over — Germany, France, Japan, the Netherlands, Switzerland. But lots of beginners have never seen or heard of it. For their benefit, here's how this mount works:

One end of a board (the larger the better) is cut off at the angle of your latitude. Two boards at least a foot long are hinged together at one end and one of them is attached to the angled face. At 11.4" from the center of the hinge pin, drill a hole in the attached board to allow passage of a 1/4-20 bolt. Countersink a 1/4-20 nut into the board to allow the bolt to turn and push against the outer board. If the bolt has 20 threads per inch, turning the bolt at the convenient rate of one r.p.m. will cause the boards to open one inch (twenty threads) in 20 minutes. The tangent of the opened angle is 1/11.4 = 0.0877 (corresponding to an angle of approximately 5°), closely matching the sky's apparent motion of 5° in 20 minutes (15° per hour). You attach your camera anywhere on the outer board — with a ball and socket, a tripod head, or a couple of metal angles to make a directional head. The mount takes about an hour to make, and will cost around $10 — if you buy the tripod head rather than making your own.

Setting up the Haig mount is easy. Take the mount out and set it on a firm surface such as a table or bench. Then sight along the edge of the hinge until Polaris is just barely hidden. Attach your camera, pick a subject, and shoot.

At this point, most astrophotographers will be cringing at the spectacular lack of "precision polar alignment" and "precise tracking." Let's take a look at just how much error can be tolerated in polar alignment, in terms of image trailing on the film, according to the formula in Haig's article.

Of course, the trail length depends on where the camera points relative to the azimuth of misalignment, and on the declination of the object being tracked. The worst possible trail length, in degrees, can be approximated by:

$$T \times A/230,$$

where T is the exposure time in minutes, and A is the angle that the mount is misaligned in degrees. Polaris lies about 0.8° from the celestial pole. If you line things up on Polaris rather than the pole, and expose for 15 minutes, the longest trail should be 15 x .8/230 = .0521°. The tangent of the angular trail length multiplied by the focal length of the lens gives the trail length expressed in the unit of the lens length (millimeters or inches). For a 50 mm lens aligned as above:

tan .0521 = .00087 x 50 mm = .043 mm

of trail. For the very common 135 mm telephoto lens:

.00087 x 135 mm = .117 mm.

As a general rule, trails 0.75 mm long do not appear objectionable. The 50 mm lens performs well within that limit, but the 135 mm lens in the example produces trails over twice as long as desirable. With that lens, a ten minute exposure would be the maximum before trailing becomes objectionable:

10 min. x .8/230 = .034;

tan .034 = .000524 x 135 mm = .07 mm.

Once the mount is aligned and the camera in place, pick a subject and aim.

Next, set the drive screw so that it just touches the upper board. Imagining the back of the board as a clock face, set the screw arm at the 12 o'clock position. Turn the shutter speed dial to the Time or Bulb setting, trip the shutter, and lock it open. Begin turning the screw arm slowly, so that it makes one revolution per minute. A useful accessory at this point is a recording of a voice counting seconds, or a segment of a WWV broadcast.

You can time the turning with a watch but it's hard to see a sweep second hand at night. The important thing is to keep the drive screw in synchronization with a clock. The longer the focal length of the lens, the more critical the sync must be, due to the more highly magnified image (and more magnified errors).

Numerous exposure guides exist for various celestial objects. For star fields, three to five minutes is a good place to begin. Your normal lens at f/1.4 will record down to 11th magnitude in three minutes or so. The maximum exposure time you can achieve with a Haig mount is about 20 minutes. After that, the screw begins to slip on the surface of the top board, nature's subtle way of saying that:

$$\tan(A) \neq A;$$

therefore, the stars will begin to trail. However, a 20 minute exposure with fast films such as the new Kodak 400 print or slide films will record an amazing number of stars.

The Haig mount is an ideal system to use in sky patrols such as Ben Mayer's PROBLICOM Project, or constellation photography.

Ken S. Hulme
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Dave Eicher, Editor Telephone (513) 523-5554

◄3

reporting of some of the events they undertake. A different group could be highlighted each month with a complete history of the organization, what they do, what sort of facilities they have, etc., with smaller sections covering amateur news items or reports on some of their activities. Any one of the above could be used or perhaps some other system.

I would like to know what other amateur groups across the country are like and what they are doing and I know for a fact that many of my friends have the same feelings about this subject.

Steven E. Hubbard
32 Farm Lane
Westwood, MA 02090

Dear Mr. Hubbard / I would happily increase the amount of coverage in TELESCOPE MAKING of amateur activities, group observatories, and club histories (such as appeared in TM#2).

I seriously doubt that there is adequate support for an independent magazine of amateur activites to survive, and I would hesitate to add another section to already-crowded ASTRONOMY. If I am overwhelmed with reader mail expressing opinions to the contrary, I will reconsider my opinion.

-- R.L.B.

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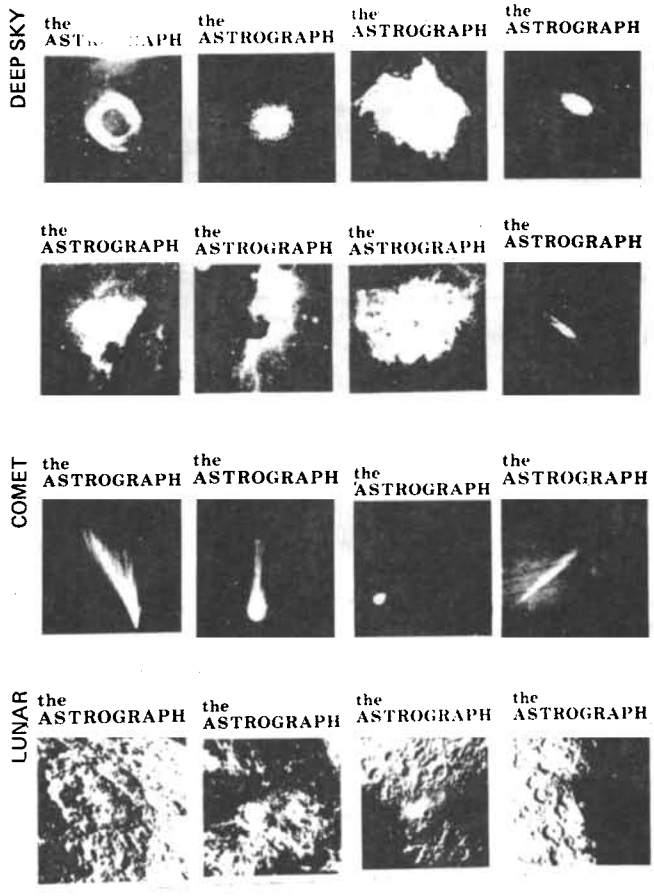
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